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FATIGUE, CREEP AND STRESS-RUPTURE PROPERTIES OF NICROTUNG, SUPER A-286, AND INCONEL 718

A. A. BLATHERWICK
A. CERS

UNIVERSITY OF MINNESOTA

TECHNICAL REPORT AFML-TR-65-447
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RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

The work reported herein was conducted by the Department of Aeronautics and Engineering Mechanics, at the University of Minnesota, Minneapolis, Minnesota 55455, under United States Air Force Contracts AF 33(657)-7453 and AF 33(615)-1122. The contracts were initiated under Project No. 7351, Task No. 735106 and Project No. 687381, Task No. 738106. The work was monitored by the Air Force Materials Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Dayton, Ohio with Mr. C. L. Harmsworth and Mr. David C. Watson, MAAM, acting as Project Engineers.

The following personnel and students in the University of Minnesota contributed to this program: Messrs. Roger Erickson, William Marquardt, Maurice Odegard, Gene Jorgensen, Roger Peterson and David Sippel, Mrs. Marlene Robertson, and Miss Brigitte Sohnleitner.

This report covers work done during the period March, 1960 to July 31, 1965. Manuscript of this report was released by the authors August 1965 for publication as an RTD Technical Report.

This technical report has been reviewed and is approved.

D. A. Shinn
Chief, Materials Information Branch
Materials Applications Division
Air Force Materials Laboratory

NOTE: The Contractor distributed 50 PREPRINT copies of this report with an erroneous Technical Report Number, AFML-TR-65-329. The correct number is AFML-TR-65-447. Reports with the new and correct number have been sent to those who have received the PREPRINT copies.

ABSTRACT

The fatigue, creep, and stress rupture properties of three super alloys: Nicrotung, Super A-286, and Inconel 718 were determined at elevated temperatures. The specimens of Nicrotung were investment cast, Super A-286 were machined from bar stock, while the Inconel 718 was tested in sheet form. The specimens were tested in axial-stress machines.

Fatigue and stress-rupture data are presented in the form of S-N diagrams, and the effect of combinations of alternating and mean stresses is shown by means of stress range diagrams. Creep data are given in the form of creep-time curves, and for design purposes creep strength curves are presented.

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I. SUMMARY

An experimental program has been conducted to determine the fatigue, creep, and stress-rupture properties of the super alloys Nicrotung, Super A-286, and Inconel 718 at room and elevated temperatures. All tests were performed in axial-stress machines capable of maintaining any alternating stress amplitude and superposing it on any desired static stress. Several ratios of alternating to mean stress (A ratios) were employed so that the complete range of stress from completely reversed ($A = \infty$) to static creep rupture ($A = 0$) was covered.

The specimens of Nicrotung were investment cast in cylindrical form. Super A-286 specimens were also cylindrical but were machined from bar stock. Inconel 718 was tested in sheet form, 0.066" thick. Notched as well as unnotched specimens were used in both the bar and sheet forms. The Nicrotung specimens were tested at 1200°F, 1500°F, and 1700°F, only. Super A-286 was tested at 800°F, 1000°F, 1100°F, and 1250°F. The test temperatures for Inconel 718 were 75°F, 1000°F, 1200°F, and 1400°F.

The fatigue data on Nicrotung are presented in the form of S-N diagrams in Figures 14 through 18 and summarized in stress-range diagrams in Figures 19 and 20. Creep data are shown in Figures 21 through 24, and the creep-strength design curves are given in Figures 25 and 26. Minimum creep rates are shown in Figure 27.

The fatigue data for Super A-286 are given as S-N diagrams in Figures 28 through 36 and the stress-range diagrams are presented in Figures 37 through 40. The creep data are shown in Figures 41 through 47 and minimum creep rates in Figures 48 to 50. The creep strength design curves are given in Figures 51 to 53. Special low-level creep tests were conducted on this material to determine the 0.2% creep strength. These results are given as creep curves in Figures 54 to 62, and Figures 63 to 68 give the stresses required to produce 0.2% plastic strain as a function of time.

The fatigue data for Inconel 718 are given as S-N diagrams in Figures 70 through 78 and summarized in stress-range diagrams in Figures 79 to 82. Creep data are presented in Figures 83 through 91 and creep-strength design curves in Figures 92 through 99. Minimum creep rates are given in Figures 100 through 103.

II. INTRODUCTION

The demands for improved performance of jet engines and gas turbines have led to the development of super alloys which can withstand high static and dynamic stresses at elevated temperatures for long periods of time. Similar requirements of materials

for use in the super-sonic transport planes, now being planned, have increased the interest in materials which can withstand these severe conditions.

It is essential that design data on the mechanical behavior of new alloys be obtained and that these data be as comprehensive as practicable. Accordingly, this program was undertaken on three super alloys: Nicrotung, Super A-286, and Inconel 718. The objectives of the program were to obtain fatigue, creep, and stress rupture data on these alloys in the temperature regimes to which they were best suited and which are expected in the applications which they may serve.

This report outlines the program that was conducted and presents the results in the form of tables and diagrams which portray the behavior of the materials and provide the design information required. The results for Nicrotung are given first, and they are followed by those for Super-A-286 and Inconel 718 in that order.

III. EXPERIMENTAL PROGRAM, EQUIPMENT AND PROCEDURES

3.1 Testing Program.

This investigation was conducted under axial load on unnotched and notched specimens of precision cast Nicrotung, Super A-286 bar and Inconel 718 sheet. The stress conditions were chosen to cover the range from a reversed type to a creep rupture test with intermediate conditions at specified alternating-to-mean stress ratios A. The stress amplitudes were adjusted to produce failure in a range from 10^4 to 2.6×10^7 cycles, or from 3 minutes to 120 hours at a frequency of 3600 cpm. Creep was recorded at low and intermediate stress ratios within the limitations imposed by machine vibrations and magnitude of the creep.

The cast Nicrotung was tested at the following test temperatures and alternating-to-mean stress ratios A: 1200°F and A = ∞; 1500°F and A = ∞, 1.0, 0.25, 0; and 1700°F and A = ∞, 1.0, 0.25 and 0. The Nicrotung specimens were intended to be tested in the "as cast" condition. This condition was used with the unnotched specimens, but due to excessive eccentricity of the cast notch, it was necessary to re-machine the notched specimens. The theoretical stress concentration factor for the notched specimens was 2.0.

The test conditions for the Super A-286 were: 800°F at A = ∞ 0.67, 0.25; 1000°F at A = ∞, 1.0, 0.35, 0.15, 0; 1100°F at A = ∞ 0.67, 0.25, 0; and 1250°F at A = ∞, 1.5, 0.67, and 0. The theoretical stress concentration factor of the notched specimens was 3.4.

In addition, the conventional fatigue program for this alloy was expanded to determine stress levels that produce 0.2% total

plastic deformation at a few test temperatures and stress ratios, A, overlapping the conditions of the fatigue failure program, i.e., at 1000°F at A = 0.35 and 0.15; 1100°F at A = 0.25 and 0.10; and 1250°F at A = 1.5 and 0.67.

The testing program for the Inconel 718 sheet included test conditions most significant for this alloy and its application. The test temperature and alternating-to-mean stress ratios A were: room temperature (75°F) at A = ∞ , 0.67, 0; 1000°F at A = ∞ , 1,0 0.67, 0.25, 0.10, 0; 1200°F at A = ∞ , 1.0, 0; and 1400°F at A = ∞ 1.5, 0.67, 0.25 and 0. The specimen orientation with respect to the sheet rolling direction was transverse. A few spot tests with longitudinally oriented specimens were conducted at room temperature (75°F) and A = ∞ , and 0; 1000°F at A = ∞ , 1.0, 0 and 1400°F at A = ∞ , 1.5, 0.25, and 0. The theoretical stress concentration factor for the notched specimens of this alloy was 3.0.

The testing programs for the alloys of this investigation are shown in Table I.

3.2 Specimens and Testing Equipment.

3.2.1 Test Materials and Specimen Preparation. The alloys of this investigation and information about their chemical composition, heat treatment and source are shown in Table II.

The precision cast Nicrotung specimens were received from the Materials Laboratory at Wright-Patterson Air Force Base. The original request to test Nicrotung specimens "as cast" could be complied with only for the unnotched specimens. Even those test bars had a run-out in excess of 0.050 in. By use of an improvised centering jig, which held the specimen at its test section, the unnotched specimens could be centered and threaded. This technique reduced the run-out to 0.012 in., average.

The cast notches of the notched specimens, in addition to the excessive run-out, were rather badly malformed necessitating remachining. The notch contour was corrected by grinding with a contour-dressed wheel and finished using the standard specimen finishing techniques as described in detail in References 1 and 2.

No further finishing nor heat treating processes were given to the Nicrotung specimens. The specimen configuration used in the Nicrotung investigation is shown in Figure 1.

The Super A-286 specimens were received from the Materials Laboratory and were prepared by Metcut Research Associates, Inc. The theoretical stress concentration factor of the notched specimens was 3.4. The specimens used in the Super A-286 investigation are shown in Figure 2.

The Inconel 718 sheet was received from the International Nickel Company in cold rolled and 1800°F annealed and waterquenched

condition. The final reduction, before the annealing treatment, was 20%. The remainder of the heat treatment, which consisted of double ageing at 1325° and 1150°F in hydrogen atmosphere, was performed on finished specimens for the University of Minnesota by Metallurgical, Inc. - commercial heat treating specialists. The location and orientation of the specimens within the sheets is shown in Figures 4, 5, and 6.

Previous fatigue investigations at the University of Minnesota had been conducted primarily on round specimens (Ref. 2-6). The new program on sheet specimens necessitated the development of grips and buckling restrainers which would permit testing under reversed axial stress ($A = \infty$) as well as under tensile mean stress. The development study included a series of photoelastic tests to determine the optimum design of grips and the fatigue specimen. The resultant fatigue test specimen, shown in Figure 3, has a gage length which is 0.3 in. wide and 1.0 in. long. The gripping ends are 2.0 in. wide with one punched and reamed 3/4 in. diameter holding pin hole on each end. The edge-notched specimens, with a theoretical stress concentration factor of 3.0 have a minimum notch width of 0.3 in., an overall width of 0.448 in., and a root radius of 0.022 in.

The need for controlled specimen finishing was also recognized and a new sheet specimen edge-polishing machine was built. The edge polisher, described to some detail in Section 3.2.4, is a new addition to other specialized equipment for test specimen preparation built at the University of Minnesota (1 & 2). Essentially, the sheet specimen preparation consisted of the following steps: (1) The specimen blanks were sheared 1/16 in. oversize and numbered as shown in Figures 4, 5, and 6. (2) The 3/4 in. diameter pin holes were punched in a jig die-punch and reamed in a reaming jig to insure a constant pin-to-pin distance. (3) The blanks were stacked up on 2 pins, 4-deep and their edges shaped to size and ground for transverse symmetry within + 0.001 in. (4) The test section was roughed out on a horizontal milling machine to approximately 0.050 in. oversize in width. (5) Each 4-specimen stack was installed on guide pins on the edge polisher and, using #150 and #240 grit belts, the oversize width was removed, simultaneously forming the test section. The contour of the test section was produced by the template and cam follower feature of the polishing machine. (6) After forming the test section, the edges were finished with #400 grit belts. Vapor mist cooling, directed at the cutting area from two sides, was used on the grinder. The transverse symmetry of the test section with respect to the center line through the holding pin holes was held to less than 0.0005 in.

The notched specimens were machined similarly by milling and belt-grinding before the machining of the notch. After forming the test section in the edge grinder, the notch contour was milled with a formed cutter to a depth leaving approximately 0.030 in. material which was subsequently removed by grinding with a dressed

wheel. The notch milling operation used a formed cutter ground to correspond to the notch contour. The grinding wheel was dressed to the final notch contour, i.e., 60° included angle, 0.022 in. root radius, with a Brown & Sharpe radius and tangent dresser.

Considerable care was exercised during the milling and grinding operations. As the final dimension of a given operation was approached, feeds and cuts were reduced to avoid effects of cold working and residual stresses. During the milling operation a lubricating cutting fluid was continuously recirculated over the work. On the edge grinder a vapor mist cooling unit (Precise Products Corporation) was used. The notch grinding operation used Johnson TD-131 cooling fluid.

The heat treatment cycle was performed on finished specimens. It consisted of double ageing at 1325°F for 8 hrs., furnace cooling to 1150°F and holding at 1150°F to complete a total of 18 hrs. in furnace. During the heat treatment the specimens were held down with a surface-ground plate to prevent warpage. To keep oxidization at a minimum, hydrogen atmosphere was used.

3.2.2 Testing Equipment for Round Specimens. All test programs of this investigation were conducted in axial stress fatigue-dynamic creep machines described in a previous publication (7). The alternating forces are produced by a mechanical oscillator operating at 3600 cpm. Simultaneously, mean forces may be applied by means of calibrated helical springs, thus providing means for testing at various alternating-to-mean stress ratios. The preload is automatically controlled keeping the mean forces constant and compensating for specimen elongation during the test.

The tests at elevated temperatures were conducted in resistance type shunt furnaces controlled to ± 5°F by Honeywell ElectronikK 15 proportioning control systems (6). The temperature variation over the test section of the specimen was held to less than ± 5°F.

The testing of Inconel 718 sheet necessitated slight modifications of the equipment to accommodate sheet grips and a larger furnace. The equipment used in this program is described in Section 3.2.3.

Creep was measured with a linear variable differential transformer-type extensometer which has been previously described (2). A slight modification was required to permit its attachment to the fillet shoulders. This arrangement thus sensed the total elongation in the test section and both fillets.

3.2.3 Testing Equipment for Sheet Specimens. The testing equipment used in the Inconel 718 sheet program is basically the same as previously described (7) and used for the Super A-286 and Nicrotung bar specimen testing. Slight modifications were necessary to accommodate sheet grips and a split three-zone furnace as

shown in Figure 7. The upper crosshead, which holds the fixed end of the specimen-grip assembly, was re-designed for support by two columns. This modification removes the original third column, providing access to the front of the split furnace for specimen installation.

The sheet grips consist of two surface-ground Haynes Alloy No. 25 plates held in grip holders by two stripper bolts, as shown in Figure 8. The specimen clamping surfaces of the grip plates are step ground for the thickness of the particular sheet material and bored to a push fit for the specially-fitted specimen clamping pin-bolt. Considerable care was exercised during the machining processes to insure dimensional symmetry reducing possible eccentric loading of the test specimen. The installed grip and grip-holder assembly, after a check-out with a strain gaged specimen, does not have to be removed for specimen installation, thus providing means for rapid specimen exchange. With due care exercised during the grip installation, the bending stresses are kept below 6%. Initially, the tightening of the specimen holding pin-bolts with conventional wrenches caused clamping distortion of the specimen and grips. This condition was alleviated by the design of a simple counter-torque wrench shown in Figure 9. This wrench permits the application of equal and opposite torques to the pin-bolt. The wrench is strain gaged to insure consistency in specimen gripping tightness.

For testing at stress ratios, A, larger than 1.0 including reversed stress, $A = \infty$, a specimen buckling restrainer was used. It consists of two bolts holding against the specimen a set of two contact low-friction plates as shown in Figure 10. The first experiment with the buckling restrainer used carbon plates as the anti-friction element. Because of possible carburization of the Inconel 718, carbon was replaced with hot pressed boron nitride. Boron nitride works satisfactorily at temperatures up to approximately 1000°F. Although the manufacturer of the boron nitride claims it to be inert at temperatures higher than 1000°F, gradually some adhesion was experienced at temperatures above 1000°F. This adhesion was observed mainly on unnotched specimens, suggesting fretting between the boron and the specimen as one of the causes for the adhesion. Various attempts to alleviate this adhesion were unsuccessful. Because no other anti-friction material, suitable for high temperature use, could be found, and the use of carbon, due to the carburization danger of the present test material, was not permissible, the use of boron nitride was continued. No other detrimental effects could be observed at lower stress ratios and temperatures. The effects of the boron adhesion and possible minimization are presently under further study.

The furnaces were standard commercial three-zone split furnaces manufactured by Marshall Company, Figure 7. All three zones were connected to one reactor-controlled power supply with variable autotransformers across the center and top zones for adjustment of thermal gradients. One centrally-mounted thermocouple controlled the reactor power output to the furnace. Three thermocouples,

distributed over the test section and both fillets, were used for thermal gradient monitoring. The temperature distribution, including the control temperature, was kept well within $\pm$ 5°F.

The creep of the sheet specimens was recorded by means of a linear variable differential transformer-type extensometer previously described (2). It was modified for use with sheet specimens as shown in Figure 11. The recorded creep elongation includes that of the test section and both fillets. The modifications of the extensometer were such, that it could be used on specimens with the buckling restrainer in place.

3.2.4 Sheet Specimen Polishing Machine. Recognizing the importance of various factors in quality control of fatigue specimen preparation, (i.e. transverse and longitudinal symmetry of the test section, cross-sectional area at the center of the gage length slightly but consistently less than the ends to compensate for the effects of fillets, longitudinal edge finish and its reproducibility, controlled and well cooled material removal, etc.), a semi-automatic edge polishing machine was found to be desirable. As no such equipment was commercially available, it was necessary to design and construct a suitable machine. Figures 12 and 13 show the polishing machine.

Essentially, the edge polisher is a contour-drum grinder having a line contact between the specimen stack and a ½ in. wide abrasive belt passing over the rotating drum A and the belt drive pulley I. At the same time the grinding drum assembly follows the template B, which is formed according to the desired contour of the specimen test section. The template mount is adjustable, E, for correction of a possible end-to-end taper. The depth of cut is adjustable by means of the micrometer screw C and is measured more precisely with a hand micrometer against the reference block H. The traversing of the drum grinder is accomplished by the motor driven lead screw D. The roughed-out specimen blanks are clamped with toggle-clamps F on holding pins G which are mounted on the fixed specimen support table K. During the operation of the grinder two "Vapor Lub", mist cooling nozzles are directed from both sides at the cutting area. The refrigerating and lubricating action of the "Vapor Lub" unit plus the limited contact area between the specimen blanks and the grinding belt promotes a well cooled material removal. To keep this "line contact" at minimum, the ratio of the radius of the specimen fillets to the grinding-drum radius must be as large as possible.

3.3 Testing Procedures.

The testing procedures used during the fatigue testing of Nicrotung and Super A-286 were as previously described for other materials (5,6). After holding the specimen at the test temperature for a period sufficient for the grip and specimen assembly to reach a thermal equilibrium, the alternating load was applied. This "soaking period" was determined by observing the drift of an installed extensometer. Thereafter the mean load was applied at a loading rate of approximately 17,000 psi. per minute. The reported

time to failure is the time from the instant when full load (alternating plus mean) is reached. The creep time curves show the total elongation beyond the full load. To determine unit creep strain, corrections for creep in the specimen fillets were made as previously described (2).

The testing procedures used during the Inconel 718 sheet testing were similar except for the sequence in applying the alternating and mean loads. Here, at the low stress ratios, where the buckling restrainer could be omitted, the mean loads had to be applied first, to prevent the sheet specimens from buckling. For the sake of uniformity this sequence was used during the whole Inconel 718 program.

The testing procedures during the program extension on Super A-286 for the determination of the 0.2% total plastic deformation were slightly different. The creep recorder was started and consecutively the alternating and mean loads were applied. After a suitable period of time the test was stopped and the elastic contraction recorded and subsequently subtracted from the initial elongation. The creep data therefore contains only the plastic deformation.

IV. RESULTS AND DISCUSSION

4.1 Nicrotung.

In this section, all of the results obtained from the testing of Nicrotung are presented and their significance discussed. The fatigue results are given first in the form of S-N diagrams. The effect of stress combinations is assessed by means of the stress-range diagrams. Finally, the creep data are presented and discussed.

4.1.1 Fatigue. The results of all fatigue tests on Nicrotung are list in Table IV and the data are plotted in the form of S-N diagrams in Figures 14 through 18. Figures 14 and 15 give the results at 1500°F for unnotched (K_t = 1.0) and notched (K_t = 2.0) specimens respectively. Separate curves are shown for each of the A ratios (ratio of alternating-to-mean stress) 0, 0.25, 1.0, and ∞.

Figures 16 and 17 give the 1700°F data for unnotched and notched specimens respectively. In Figure 18, separate S-N curves are plotted for each test temperature at A = ∞ for both notched and unnotched specimens. The only 1200°F tests were run at A = ∞, so these curves are shown only in this figure.

At 1500°F, the curves fall in the usual order, the static creep-rupture curves being highest and the others falling lower as the A ratio increases. For 1700°F, however, there is some inversion, the creep-rupture (A = 0) curve for unnotched specimens falling below the curves for A = 0.25 and 1.0. For notched specimens, the creep-rupture curve crosses the A = 0.25 curve only at the long-life end. This inversion of curves is an indication that at this temperature,

creep is a more significant factor than fatigue. The fact that the notched specimens have higher strength than unnotched ones for A ratios of 1.0 and lower is a further indication of the validity of this conclusion. The lower-stress regions at the shoulders of the notches inhibit creep deformation.

The notched specimens were generally stronger than the unnotched ones, even at A = ∞. This peculiar behavior is probably due to the specimen preparation. The unnotched specimens were tested as cast, while the notches were ground and polished before testing. Irregularities and casting seams were apparent on the surface of the unnotched specimens, and this condition undoubtedly resulted in stress concentrations higher than the rather mild stress concentration produced by the machined notch.

4.1.2 Constant-Life Diagrams. Figures 19 and 20 give the combinations of stresses resulting in failure at 1, 10, and 100 hours for 1500°F and 1700°F respectively. The plotted points on the radial lines representing A = 0, 0.25, 1.0, and ∞ were taken from the S-N curves in Figures 14 to 17.

Here again, the inverted order of notched and unnotched specimens is evident. The notched specimens exhibit higher fatigue strength than the unnotched ones.

4.1.3 Creep. Figures 21 to 24, inclusive present the creep results at the two test temperatures and the two A ratios at which creep was measured. Figures 21 and 22 are the static creep curves for 1500°F and 1700°F respectively, while in Figures 23 and 24 the dynamic creep curves for A=0.25 are given.

The static creep curves exhibit the usual behavior at both 1500°F and 1700°F. The high-stress curves are steep and rupture occurs in relatively short time. At the lower stresses, the secondary and tertiary stages of creep are evident.

The dynamic creep curves, Figures 23 and 24, are also quite normal. One inversion is evident at 1500°F where the creep rate at 62,500 psi is higher than that at 65,000 psi for part of the life. This inversion is believed to be due to scatter rather than any behavioral effect.

Figures 25 and 26 present the creep strengths for this material for 1500°F and 1700°F, respectively. Each figure contains two sets of curves; one for static creep (A = 0) and the other for dynamic creep (A = 0.25). Each set has several curves, each pertaining to a given creep strain. These curves also have the usual characteristics, and there are no unexpected results. Comparing the two figures, it is obvious that the creep strength at 1700°F is considerably lower (slightly over half) than the strength at 1500°F.

Figure 27 gives the minimum creep rate as a function of mean stress for both temperatures and A ratios. At 1500°F the minimum creep rate, for a given stress, is much higher at A = 0.25 than at

A = 0. It should be noted, however, that the mean stress is the variable considered here. The maximum stress in the cycle, for A = 0.25, would be 25% higher.

4.2 Super A-286.

4.2.1 Fatigue. The data obtained at 800°F, 1000°F, 1100°F, and 1250°F are listed in Table V and are plotted as S-N diagrams in Figures 28 through 36. Figures 28 and 29 give the 800°F results for unnotched and notched specimens; Figures 30 and 31 are for 1000°F tests; Figures 32 and 33 give 1100°F data; and Figures 34 and 35 show the 1250°F results. As is apparent, not all A ratios were used at each temperature.

The effect of temperature is readily discernible in Figure 36 where the separate S-N curves are shown for each temperature at A = ∞. Increasing temperature reduces the fatigue strength for unnotched specimens. Temperature is not nearly as significant, however, for notched specimens whose curves are closely bunched at the long-life end.

4.2.2 Constant-Life Diagrams. The constant-life diagrams for the several test temperatures are given in Figures 37 to 40, inclusive. No static creep tests were conducted at 800°F, (Figure 37) nor were fatigue tests run at A = ∞ on notched specimens. These diagrams are therefore somewhat limited. At the other temperatures, however, the diagrams are complete.

These curves also display the usual pattern; the unnotched specimens having curves that are generally concave downward while the notched curves are concave upward over the stress region in which alternating stress is predominant. This effect is probably the result of the higher creep strength of notched specimens. It is apparent, again, from these curves that for A ratios less than about 0.15, the notched strength is greater than that of unnotched specimens. As was discussed earlier, this effect is attributable to a reinforcing of the high-stress region at the root of the notch by the lower-stressed regions immediately surrounding it. This reinforcement inhibits creep deformation, but does not prevent the nucleation and propagation of fatigue cracks.

4.2.3 Creep. Figures 41 through 47 give the creep data obtained at 1000°F, 1100°F, and 1250°F for both static and dynamic tests. Figures 41, 42, and 43 are the 1000°F data at A = 0, 0.15, and 0.35, respectively. Figure 44 contains the 1100°F results at A = 0.25, and Figures 45, 46, and 47 present the 1250°F results for A = 0, 0.67, and 1.5, respectively. At 1100°F, creep data were taken at only one A ratio, that of 0.25. All of these curves follow the usual expected pattern.

Figures 48, 49, and 50 give the minimum creep rate as a function of stress for 1000°F, 1100°F, and 1250°F, respectively. In each figure, the various curves pertain to a given A ratio. It is

apparent that higher stresses are required to produce a given creep rate as the A ratio decreases. Again, it is important in interpreting this observation to recognize that the stress variable plotted here is mean stress, not the maximum stress in the cycle.

The creep-strength design curves for various strains are given in Figures 51, 52, and 53 for 1000°F, 1100°F, and 1250°F, respectively. For 1000°F and 1250°F, several A ratios are included, as indicated by the codes, while for 1100°F, the one A ratio (0.25) is given. No unusual behavior is evident in these figures.

4.2.4 Low-Level Creep. A special series of creep tests was conducted on this material at stresses considerably below those which would result in stress rupture. The creep strains were naturally quite small as well. Figures 54 through 62 present the results of these tests in the form of creep-time curves. In these graphs plastic deformation is plotted against time. No failures occurred, and the curves are terminated wherever the tests were arbitrarily stopped.

Figures 54, 55, and 56 give the 1000°F data for A = 0, 0.15, and 0.35, respectively. The 1100°F data are given in Figures 57, 58, and 59 for A = 0, 0.10, and 0.25, respectively, and in Figures 60, 61, and 62, the 1250°F results are shown for A ratios of 0, 0.67, and 1.5, respectively.

Each curve represents the results of a single test. Since there are some obvious inversions, it is evident that there is a considerable disparity in creep rate from specimen to specimen. Because the measured deformation was quite small, the sensitivity of measurement was necessarily high and therefore considerable scatter could be expected.

Figures 63 through 68 give the stresses required to produce 0.2% plastic deformation as a function of time and number of cycles. These are analogous to stress-rupture curves except that 0.2% plastic deformation is the criterion used rather than failure.

The data contained in the curves described above are summarized in the stress range diagrams in Figure 69. This graph gives the stress combinations which produce a 0.2% plastic deformation in 100 hours. There is one curve for each of the three test temperatures, 1000°F, 1100°F, and 1250°F. For comparison, the 100 hour constant-life curves are superposed on this graph. The fact that the curves are steep indicates that the presence of an alternating stress has relatively little effect on the mean stress to produce the given 0.2% plastic deformation.

4.3 Inconel 718.

4.3.1 Static Tensile Properties. The results of the static tensile tests for each of the test temperatures are given in Table VII. The expected trends are evident with the ultimate strength,

yield strength, and modulus of elasticity dropping off as the temperature is increased. The ductility, on the other hand, as indicated by per cent elongation and reduction in area, appears to be maximum at 1000°F and then drops off at 1200°F and 1400°F. There have been other similar results for materials of the same kind (8). The longitudinal and transverse specimens yielded substantially the same results throughout.

4.3.2 Fatigue. The fatigue and creep rupture data for Inconel 718 are listed in Table VIII, and the S-N diagrams are given in Figures 70 through 77 for unnotched and notched specimens and for the test temperatures: 75°F, 1000°F, 1200°F, and 1400°F. In each graph, a separate curve is shown for each A ratio.

There is considerably more scatter in these data than in the data previously presented. It was expected that the sheet specimens would display less consistent behavior because of their greater susceptibility to spurious effects. These data certainly confirm that hypothesis.

Most of the data obtained on this material were from specimens whose axis was transverse to the rolling direction of the sheets. The curves are drawn through the points from these data. A few tests were run on specimens whose axis was in the longitudinal direction. These points are distinguished from the others by the indicated code on the diagrams. It is apparent that these longitudinal points fit the curves as well as the transverse, and therefore no directional effect is evident.

Figure 78 shows the effect of temperature at $A = \infty$. Each S-N curve is for a given temperature, and the two sets are the results from notched and unnotched specimens. The 75°F curve for unnotched specimens is steeper and therefore indicates lower fatigue strengths at long life than do the elevated temperature curves.

4.3.3 Constant-Life Diagrams. Figures 79 to 82 are the constant-life diagrams for Inconel 718 at 75°F, 1000°F, 1200°F, and 1400°F, respectively. In Figure 82, the one-hour and 10-hour curves for unnotched specimens at 1400°F are dashed to the left of $A = 1.5$, because the points for $A = \infty$ are not realistic (lower alternating stress than at $A = 1.5$). This behavior is probably due to the effect of the compression guides. At this temperature and A ratio, there was considerable adhesion of the boron nitride from the guide plates to the specimen. This action likely caused some fretting and resulted in reduced fatigue strength. The consistency of the other points on these curves lends support to this conclusion.

A noticeable difference between these diagrams and those for Nicrotung and Super A-286 is the relation between the notched and unnotched curves at low A ratios. For the Nicrotung and Super A-286

the strength of the notched specimens was considerably higher than for unnotched ones at A ratios less than about 0.2 (as indicated by the curves crossing). For Inconel 718, however, the notched strength does not exceed that of unnotched specimens at any A ratio (except by a small amount at $75^{\circ}F$ and $1000^{\circ}F$ and $A = 0$). It is believed that this is an effect of the specimen rather than a material behavior, however. The ratio of the volume of material at low stress in sheet specimens to the surrounding high-stress volume at the notched root is considerably lower than the corresponding ratio for round specimens. Consequently, the reinforcing effect of the low-stress region in containing creep deformation in notched sheet specimens is lower. Therefore, the creep strength, as determined by notched sheet specimens is lower than one would expect to observe with round specimens.

4.3.4 <u>Creep</u>. The basic creep-time curves are given in Figures 83 through 91. In some cases curves are shown for both transverse and longitudinal specimens. No unusual behavior is exhibited by these curves.

The creep-strength design curves are given in Figures 92 through 99. Here, the families of curves giving the stress that can be endured for a given time without the creep strain exceeding a given value are shown. These curves are quite normal. It is worth noting, however, that the creep strength of the longitudinal specimens is somewhat lower than that of the transverse specimens in all cases.

Figures 100 through 103 give the minimum creep rates as a function of mean stress. The higher creep strength of the transverse specimens is also reflected in these curves. The minimum creep rates of transverse specimens are lower in all cases than those of the longitudinal specimens.

V. CONCLUDING REMARKS

Each of the three alloys, Nicrotung, Super A-286, and Inconel 718, tested in this program has its particular characteristics and is therefore suited to certain applications. It is inappropriate to make comparisons among them. Furthermore, the properties of these materials are significantly affected by the processing and heat treatment given them and therefore comparisons with materials of like chemical composition but different ageing treatments are not meaningful, except to display the effect of that treatment.

It is worthwhile noting, however, the appropriate temperature regime of each of the alloys. Nicrotung retains its fatigue and creep strength with little decrease for temperatures up to $1500^{\circ}F$. Above this temperature the strength drops off sharply. Super A-286 displays relatively little decrease in strength up to $1100^{\circ}F$, but

at 1250°F the strengths are considerably less. Inconel 718 in sheet form shows a gradual drop in tensile and creep strengths up to 1200°F and then an abrupt decrease at 1400°F. The fatigue strength at the higher A ratios likewise decreases, but the drop is not nearly as significant.

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TABLE I

Test Program

Test Temp(^{o}F)	75		800		1000			1100		1200			1250		1400		1500		1700	
Specimen K_t	1.0	3.0	1.0	3.4	1.0	3.0	3.4	1.0	3.4	1.0	2.0	3.0	1.0	3.4	1.0	3.0	1.0	2.0	1.0	2.0
Stress Ratio A = ∞	CM_T CM_L	CM_T CM_L	CG	-	CG CM_T CM_L	CM_T CM_L	CG	CG	CG	CC CM_T CM_L	CC	CM_T	CG	CG	CM_T CM_L	CM_T CM_L	CC	CC	CC	CC
1.5	-	-	-	-	-	-	-	-	-	-	-	-	CG CG_*	CG	CM_T CM_L	CM_T CM_L	-	-	-	-
1.0	-	-	-	-	CG CM_T CM_L	CM_T CM_L	CG	-	-	CM_T	-	CM_T	-	-	-	-	CC	CC	CC	CC
0.67	CM_T	CM_T	CG	CG	CM_T	CM_T	-	CG	CG	-	-	-	CG CG_*	CG	CM_T	CM_T	-	-	-	-
0.35	-	-	-	-	CG CG_*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.25		-	CG	CG	CM_T	-	-	CG CC_*	CG	-	-	-	-	-	CM_T CM_L	CM_T	CC	CC	CC	CC
0.15	-	-	-	-	CG CG_*	-	CG	-	-	-	-	-	-	-	-	-	-	-	-	-
0.10	-	-	-	-		CM_T		CG_*	-	-	-	-	-	-	-	-	-	-	-	-
0	CM_T CM_L	CM_T CM_L	-	-	CG CM_T CM_L	CM_T CM_L	CG	CG	CG	CM_T	-	CM_T	CG	CG	CM_T CM_L	CM_T CM_L	CC	CC	CC	CC

CC ——— Nicrotung

CG ——— Super A-286

CG_* ——— Super A-286 (0.2% Creep)

CM_T ——— Inconel 718 - Transverse

CM_L ——— Inconel 718 - Longitudinal

TABLE II

Chemical Composition, Heat Treatment, and Source of Test Materials

Type of Alloy	Nicrotung	Super A-286	Inconel 718
Source	Materials Laboratory, RTD, Wright-Patterson Air Force Base	Allegheny Ludlum Steel Corporation	Huntington Alloy Division, The International Nickel Company
Chemical Composition	C 0.10 B 0.05 Zr 0.05 Cr 12.0 Co 10.0 W 8.0 Al 4.0 Ti 4.0 Ni Balance (61+)	C 0.046, Mo 1.35 Mn 1.20, Ti 2.05 P 0.22, Fe 53.89 S 0.006, V 0.23 Si 0.61, B 0.004 Cr 14.50 Ni 25.91 Al 0.18	C .03, Cr 19.24 Mn .31, Al .43 Fe 18.44, Ti .84 S .007, Mo 3.10 Si .21, Cb+Ta 5.16 Cu .05, Al+Ti 1.27 Ni 52.16
Received as	Precision Investment Cast Specimens	Specimens	0.067 in. cold rolled Sheet
Heat Treatment	No Heat Treatment	1650°F - 2 Hrs. Oil + 1300°F - 16 Hrs. Air	1800°F - 6 Min., Water Quench + Age at 1325°F for 8 Hrs., Furnace Cool to 1150°F and Hold at 1150°F to Complete a Total of 18 hrs. in Furnace, Air Cool.
Specimen Preparation	University of Minnesota	Metcut Research Associates Inc.	University of Minnesota

TABLE III a

Tensile Test Data for Nicrotung

Test Temp (^{o}F)	UTS (ksi)	0.02% YTS (ksi)	0.2% YTS (ksi)	Elong (%)	AR (%)
70	130.0	---	120.0	5.0	---

TABLE III b

Tensile Test Data for Super A-286

Test Temp (^{o}F)	UTS (ksi)	0.02% YTS (ksi)	0.2% YTS (ksi)	Elong (%)	AR (%)	
800	207.4	---	---	---	---	K_t=3.4
800	206.4	---	---	---		K_t=3.4
800	140.1	93.0	102.2	26.0	46.0	
800	142.6	97.6	107.7	23.5	48.0	
900	138.9	99.7	106.9	21.5	46.0	
900	139.0	92.4	102.2	23.0	47.0	
1000	137.6	99.6	110.9	20.5	45.0	
1000	136.7	101.6	109.4	20.5	47.0	
1100	131.8	102.2	111.4	22.5	44.0	
1100	131.2	101.2	110.4	21.0	43.0	
1250	108.8	93.0	106.5	15.0	18.0	
1250	110.4	100.0	108.2	16.0	17.0	

K_t ——— Theoretical Stress Concentration Factor

TABLE IV

Test Data for Microtung

Test Temperature 1200°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Elong %
CC 7243 BZ	∞	0	30.0	30.0	238.14	51,440	T.S.
7301	∞	0	32.5	32.5	136.35	29,450	
7250	∞	0	35.0	35.0	34.00	7,344	
7261	∞	0	35.0	35.0	10.89	2,352	
7275	∞	0	40.0	40.0	3.78	817	
7265	∞	0	42.5	42.5	5.50	1,188	
7269	∞	0	45.0	45.0	5.63	1,216	
7243	∞	0	50.0	50.0	0.73	158	P.S.
7284	∞	0	55.0	55.0	0.66	143	
CC 8213 CE	∞	0	30.0	30.0	169.03	36,510	T.S.
8167	∞	0	32.5	32.5	160.11	34,580	T.S.
8156	∞	0	34.0	34.0	1.10	238	
8213	∞	0	35.0	35.0	136.59	29,500	P.S.-T.S.
8158	∞	0	35.0	35.0	2.99	646	
8193	∞	0	35.0	35.0	0.44	95	
8173	∞	0	37.0	37.0	0.62	134	
8185	∞	0	37.5	37.5	0.40	86	
8180	∞	0	42.5	42.5	0.32	68	
8213	∞	0	45.0	45.0	0.40	86	P.S.
8167	∞	0	45.0	45.0	0.32	68	P.S.

Test Temperature 1500°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Elong %
CC 7231 BZ	∞	0	30.0	30.0	160.26	34,620	
7286	∞	0	30.0	30.0	143.97	31,100	
7292	∞	0	32.5	32.5	16.17	3,493	
7248	∞	0	35.0	35.0	10.70	2,311	
7257	∞	0	37.5	37.5	13.52	2,920	
7272	∞	0	40.0	40.0	88.67	19,150	
7231	∞	0	40.0	40.0	0.40	86	
7276	∞	0	42.5	42.5	2.53	546	
7253	∞	0	45.0	45.0	2.29	495	
7285	∞	0	50.0	50.0	0.86	186	

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE IV (Continued)

Test Data for Nicrotung

Test Temperature 1500°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Elong %
CC 8160 CE	∞	0	32.5	32.5	216.61	46,790	T.S.
8168	∞	0	34.0	34.0	118.84	25,670	T.S.
8226	∞	0	35.0	35.0	1.10	238	
8160	∞	0	37.5	37.5	1.55	335	P.S.
8177	∞	0	37.5	37.5	0.22	47	
8216	∞	0	40.0	40.0	0.18	40	
8168	∞	0	42.0	42.0	0.12	25	P.S.
CC 7255 BZ	1.0	19.0	19.0	38.0	214.52	46,330	T.S.
7247	1.0	21.25	21.25	42.5	71.35	15,410	
7312	1.0	23.0	23.0	46.0	82.75	17,870	
7246	1.0	23.75	23.75	47.5	51.97	11,220	
7304	1.0	25.0	25.0	50.0	4.31	931	
7251	1.0	26.0	26.0	52.0	5.57	1,203	
7262	1.0	30.0	30.0	60.0	2.03	438	
7238	1.0	33.75	33.75	67.5	1.18	254	
7277	1.0	38.75	38.75	77.5	0.32	68	
CC 8194 CE	1.0	22.5	22.5	45.0	160.46	35,550	T.S.
8212	1.0	23.75	23.75	47.5	98.12	21,620	
8169	1.0	25.0	25.0	50.0	78.24	16,900	
8172	1.0	26.0	26.0	52.0	1.97	425	
8153	1.0	28.0	28.0	56.0	0.17	36	
CC 7294 BZ	0.25	46.0	11.5	57.5	207.97	44,920	0.30 T.S.
7289	0.25	50.0	12.5	62.5	117.66	25,410	0.40
7263	0.25	52.0	13.0	65.0	35.53	7,675	0.23
7270	0.25	52.0	13.0	65.0	3.74	808	
7293	0.25	60.0	15.0	75.0	14.73	3,182	0.22
7300	0.25	64.0	16.0	80.0	1.80	389	0.24
7244	0.25	68.0	17.0	85.0	3.14	678	0.18
7237	0.25	76.0	19.0	95.0	1.18	256	0.10
7254	0.25	84.0	21.0	105.0	0.13	29	

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE IV (Continued)

Test Data for Nicrotung

Test Temperature 1500°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Elong %
CC 8183 CE	0.25	52.0	13.0	65.0	300.00	64,800	T.S.
8198	0.25	56.0	14.0	70.0	214.61	46,350	T.S.
8206	0.25	60.0	15.0	75.0	34.41	7,432	
8166	0.25	68.0	17.0	85.0	6.15	1,328	
8163	0.25	70.4	17.6	88.0	0.21	45	
8179	0.25	72.0	18.0	90.0	0.12	25	
8202	0.25	76.0	19.0	95.0	0.17	36	
CC 7305 BZ	0	65.0	0	65.0	109.40		0.58
7239	0	75.0	0	75.0	19.40		0.51
7291	0	85.0	0	85.0	5.16		0.45
7282	0	95.0	0	95.0	0.63		0.50
CC 8224 CE	0	75.0	0	75.0	141.00		
8225	0	85.0	0	85.0	10.51		
8217	0	85.0	0	85.0	9.94		
8175	0	90.0	0	90.0	21.37		
8196	0	92.5	0	92.5	1.02		
8181	0	95.0	0	95.0	0.67		
8188	0	100.0	0	100.0	0.23		
Test Temperature 1700°							
CC 7309 BZ	∞	0	20.0	20.0	235.62	50,900	T.S.
7233	∞	0	22.5	22.5	212.63	45,930	T.S.
7307	∞	0	22.5	22.5	124.55	26,900	
7288	∞	0	24.0	24.0	81.75	17,660	
7290	∞	0	25.0	25.0	83.09	18,120	
7310	∞	0	25.0	25.0	65.27	14,090	
7287	∞	0	27.0	27.0	73.83	15,950	
7266	∞	0	27.5	27.5	23.38	4,833	
7249	∞	0	28.0	28.0	61.39	13,260	
7252	∞	0	29.0	29.0	34.14	7,374	
7245	∞	0	30.0	30.0	27.72	5,985	
7235	∞	0	31.0	31.0	4.75	1,026	
7259	∞	0	33.0	33.0	0.81	175	
7308	∞	0	35.0	35.0	1.38	299	
7271	∞	0	36.0	36.0	1.78	385	
7233	∞	0	36.0	36.0	0.15	32	P.S.

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE IV (Continued)

Test Data for Nicrotung

Test Temperature 1700°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Elong %
CC 8205 CE	∞	0	25.0	25.0	187.69	40,540	T.S.
8204	∞	0	27.0	27.0	125.74	27,170	T.S.
8151	∞	0	29.0	29.0	7.67	1,657	
8182	∞	0	29.0	29.0	0.37	79	
8208	∞	0	30.0	30.0	31.56	6,817	
8204	∞	0	30.0	30.0	8.98	1,940	P.S.
8205	∞	0	30.0	30.0	0.25	54	P.S.
8209	∞	0	31.0	31.0	1.20	259	
8154	∞	0	33.0	33.0	0.18	40	
8161	∞	0	34.0	34.0	0.18	40	
CC 7241 BZ	1.0	17.0	17.0	34.0	194.09	41,920	
7296	1.0	18.75	18.75	37.5	70.91	15,310	
7242	1.0	21.5	21.5	43.0	26.05	5,627	
7232	1.0	23.75	23.75	47.5	8.97	1,933	
7306	1.0	26.0	26.0	52.0	1.35	292	
7311	1.0	27.5	27.5	55.0	0.22	47	
7280	1.0	30.0	30.0	60.0	0.13	29	
CC 8220 CE	1.0	18.75	18.75	37.5	117.44	25,370	T.S.
8230	1.0	20.0	20.0	40.0	142.98	30,890	T.S.
8149	1.0	21.5	21.5	43.0	96.80	20,910	
8228	1.0	22.5	22.5	45.0	158.05	34,140	T.S.
8215	1.0	22.5	22.5	45.0	41.92	9,054	
8150	1.0	23.75	23.75	47.5	10.76	2,324	
8230	1.0	25.0	25.0	50.0	0.06	13	P.S.
8218	1.0	26.0	26.0	52.0	1.60	346	
8229	1.0	27.5	27.5	55.0	0.10	22	
CC 7297 BZ	0.25	30.0	7.5	37.5	153.50	33,150	0.84
7236	0.25	32.0	8.0	40.0	93.06	20,100	1.02
7281	0.25	36.0	9.0	45.0	15.94	3,443	0.45
7278	0.25	40.0	10.0	50.0	6.57	1,419	1.03
7273	0.25	48.0	12.0	60.0	1.68	364	1.00
7279	0.25	58.0	14.5	72.5	0.22	47	0.90

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE IV (Continued)

Test Data for Nicrotung

Test Temperature 1700°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Elong %
CC 8184 CE	0.25	40.0	10.0	50.0	236.54	51,090	T.S.
8170	0.25	44.0	11.0	55.0	67.61	14,602	
8231	0.25	44.0	11.0	55.0	47.48	10,260	
8171	0.25	50.0	12.5	62.5	2.30	497	
8219	0.25	52.0	13.0	65.0	24.17	5,221	
8148	0.25	56.0	14.0	70.0	1.60	346	
8192	0.25	60.0	15.0	75.0	2.0	432	
8214	0.25	64.0	16.0	80.0	0.14	31	
8186	0.25	68.0	17.0	85.0	0.05	11	
8210	0.25	76.0	19.0	95.0	0.05	11	
8221	0.25	84.0	21.0	105.0	0.04	9	
8155	0.25	89.6	22.0	112.0	0.017	3.6	
CC 7264 BZ	0	33.0	0	33.0	111.28		1.60
7258	0	40.0	0	40.0	25.12		2.14
7260	0	47.5	0	47.5	8.53		2.47
7230	0	55.0	0	55.0	1.52		2.26
7303	0	65.0	0	65.0	0.32		2.49
CC 8178 CE	0	42.5	0	42.5	132.47		
8176	0	45.0	0	45.0	76.75		
8232	0	50.0	0	50.0	86.95		
8190	0	50.0	0	50.0	22.28		
8164	0	55.0	0	55.0	105.18		
8203	0	65.0	0	65.0	15.25		
8199	0	75.0	0	75.0	1.98		
8195	0	75.0	0	75.0	1.28		
8147	0	85.0	0	85.0	0.72		
8211	0	95.0	0	95.0	0.07		
8191	0	102.0	0	102.0	0.01		
8187	0	115.0	0	115.0	*		

T.S. - Test Stopped
* - Fracture Prior to Full Load

TABLE V

Test Data for Super A-286

Test Temperature 800°F

Specimen Number	Ratio A	Applied Stress, PSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
CG 7640 AK	∞	0	65.0	65.0	84.34	18,220	
7644	∞	0	67.5	67.5	48.30	10,430	
7641	∞	0	70.0	70.0	14.74	3,184	
7639	∞	0	70.0	70.0	4.87	1,052	
7642	∞	0	72.0	72.0	4.20	907	
7632	∞	0	75.0	75.0	0.48	104	
CG 7535 AK	0.67	61.8	41.2	103.0	16.38	3,537	
7533	0.67	61.8	41.2	103.0	14.01	3,026	
7629	0.67	61.8	41.2	103.0	9.72	2,100	
7524	0.67	66.0	44.0	110.0	15.69	3,390	
7556	0.67	70.5	47.0	117.5	8.00	1,728	
7541	0.67	75.0	50.0	125.0	0.22	47	
CG 7650 AM	0.67	25.5	17.0	42.5	120.08	25,940	T.S.
7607	0.67	28.5	19.0	47.5	1.30	281	
7673	0.67	31.5	21.0	52.5	0.93	201	
7677	0.67	33.0	22.0	55.0	0.92	198	
7581	0.67	33.0	22.0	55.0	0.78	168	
7654	0.67	33.0	22.0	55.0	0.53	115	
7637	0.67	33.0	22.0	55.0	0.50	108	
7626	0.67	37.5	25.0	62.5	0.60	130	
7655	0.67	39.0	26.0	65.0	0.27	58	
CG 7544 AK	0.25	105.6	26.4	132.0	236.08	5,100	
7547	0.25	108.0	27.0	135.0	56.55	12,210	
7553	0.25	110.0	27.5	137.5	101.69	21,970	
7557	0.25	112.0	28.0	140.0	16.66	3,599	
7503	0.25	112.8	28.2	141.0	41.93	9,057	
CG 7630 AM	0.25	68.0	17.0	85.0	5.85	1,264	
7591	0.25	74.0	18.5	92.5	0.48	104	
7582	0.25	78.0	19.5	97.5	0.35	76	
7661	0.25	82.0	20.5	102.5	0.23	50	
7671	0.25	84.0	21.0	105.0	0.18	40	

T.S. - Test Stopped

TABLE V (Continued)

Test Data for Super A-286

Test Temperature 1000°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
CG 7537 AK	∞	0	60.0	60.0	115.16	24,880	T.S.
7521	∞	0	60.0	60.0	43.60	9,418	T.S.
7517	∞	0	62.0	62.0	78.98	17,060	
7542	∞	0	63.5	63.5	43.35	9,363	
7560	∞	0	65.0	65.0	0.67	144	
7510	∞	0	68.0	68.0	0.08	16	
7537	∞	0	73.0	73.0	0.34	73	P.S.
CG 7635 AM	∞	0	35.0	35.0	0.80	173	
7628	∞	0	36.0	36.0	0.60	130	
7621	∞	0	37.0	37.0	0.63	137	
7645	∞	0	39.0	39.0	0.32	70	
7624	∞	0	39.0	39.0	0.32	70	
7613	∞	0	40.0	40.0	0.36	77	
7622	∞	0	42.5	42.5	0.26	56	
7610	∞	0	47.5	47.5	0.16	34	
7623	∞	0	53.0	53.0	0.07	14	
CG 7531 AK	1.0	40.0	40.0	80.0	122.95	26,560	T.S.
7496	1.0	43.0	43.0	86.0	161.64	34,910	T.S.
7523	1.0	45.0	45.0	90.0	231.75	50,050	T.S.
7559	1.0	47.5	47.5	95.0	13.23	2,858	
7494	1.0	47.5	47.5	95.0	7.82	1,689	
7540	1.0	52.5	52.5	105.0	2.84	613	
7484	1.0	52.5	52.5	105.0	1.88	405	
CG 7575 AM	1.0	20.0	20.0	40.0	142.48	30,780	T.S.
7575	1.0	21.5	21.5	43.0	22.79	4,918	P.S.-T.S.
7636	1.0	22.5	22.5	45.0	120.36	26,000	T.S.
7672	1.0	23.0	23.0	46.0	5.19	1,121	
7572	1.0	23.0	23.0	46.0	0.55	119	
7678	1.0	23.75	23.75	47.5	4.17	901	
7575	1.0	25.0	25.0	50.0	1.16	250	P.S.
7585	1.0	25.0	25.0	50.0	0.30	65	
7636	1.0	28.0	28.0	56.0	0.76	164	P.S.
7588	1.0	28.0	28.0	56.0	0.14	31	

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE V (Continued)

Test Data for Super A-286

Test Temperature 1000°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
CG 7508 AK	0.35	83.7	29.3	113.0	95.33	20,150	T.S.
7528	0.35	85.2	29.8	115.0	119.81	25,880	0.27
7530	0.35	87.0	30.5	117.4	117.47	25,380	0.34
7562	0.35	92.6	32.4	125.0	46.71	10,090	0.58
7565	0.35	96.3	33.7	130.0	23.05	4,979	
7515	0.35	96.3	33.7	130.0	21.69	4,685	0.46
7550	0.35	96.3	33.7	130.0	20.80	4,493	
7486	0.35	100.0	35.0	135.0	11.60	2,506	0.70
7501	0.35	100.0	35.0	135.0	6.30	1,361	
7549	0.35	103.7	36.3	140.0	7.74	1,672	
7498	0.35	105.2	36.8	142.0	1.41	304	1.00
CG 7424 AK	0.15	100.0	15.0	115.0	136.73	29,530	0.87 T.S.
7472	0.15	102.6	15.4	118.0	136.33	29,440	1.08 T.S.
7534	0.15	106.1	15.9	122.0	158.45	34,230	T.S.
7440	0.15	112.0	16.8	128.8	43.79	9,459	4.83
7479	0.15	117.4	17.6	135.0	3.70	799	7.52
7448	0.15	126.1	18.9	145.0	*	*	
7456	0.15	134.8	20.2	155.0	*	*	
CG 7648 AM	0.15	100.0	15.0	115.0	116.50	25,160	T.S.
7602	0.15	102.2	15.3	117.5	119.00	25,100	T.S.
7633	0.15	104.3	15.7	120.0	2.64	570	
7643	0.15	108.7	16.3	125.0	0.27	58	
7649	0.15	117.4	17.6	135.0	0.26	56	
7648	0.15	121.7	18.3	140.0	0.13	29	P.S.
CG 7561 AK	0	115.0	0	115.0	118.52		2.14 T.S.
7488	0	121.2	0	121.2	68.57		5.00
7488	0	125.0	0	125.0	68.56		P.S.
7497	0	126.1	0	126.1	24.43		24.40
7497	0	130.0	0	130.0	24.43		P.S.
7522	0	133.0	0	133.0	3.05		11.20

T.S. - Test Stopped
P.S. - Prior Stress History
* - Fracture Prior to Full Load

TABLE V (Continued)

Test Data for Super A-286

Test Temperature 1000°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
CG 7666 AM	0	145.0	0	145.0	69.53		T.S.
7578	0	150.0	0	150.0	71.04		
7681	0	160.0	0	160.0	43.38		
7675	0	170.0	0	170.0	26.15		
7652	0	180.0	0	180.0	18.75		

Test Temperature 1100°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
CG 7511 AK	∞	0	55.0	55.0	35.79	7,731	
7504	∞	0	56.0	56.0	16.76	3,620	
7589	∞	0	57.5	57.5	89.49	19,330	
7638	∞	0	58.5	58.5	61.20	13,220	
7552	∞	0	60.0	60.0	5.08	1,098	
7619	∞	0	62.0	62.0	1.71	369	
CG 7647 AM	∞	0	35.0	35.0	118.89	25,680	T.S.
7670	∞	0	36.0	36.0	2.52	544	
7648	∞	0	37.0	37.0	0.47	101	
7647	∞	0	42.5	42.5	0.18	39	P.S.
CG 7415 AK	0.67	54.0	36.0	90.0	140.53	30,350	T.S.
7526	0.67	57.0	38.0	95.0	79.89	17,260	
7558	0.67	58.2	38.8	97.0	73.29	15,830	
7554	0.67	60.0	40.0	100.0	70.97	15,330	
7505	0.67	60.0	40.0	100.0	20.33	4,391	T.S.
7502	0.67	63.0	42.0	105.0	12.28	2,653	
7525	0.67	69.0	46.0	115.0	4.44	959	
7425	0.67	72.0	48.0	120.0	2.12	457	
7546	0.67	73.5	49.0	122.5	2.86	618	
7545	0.67	78.0	52.0	130.0	0.38	83	
CG 7569 AM	0.67	31.2	20.8	52.0	192.47	41,580	T.S.
7593	0.67	33.0	22.0	55.0	33.09	7,148	
7579	0.67	34.8	23.2	58.0	4.50	972	
7597	0.67	37.2	24.8	62.0	0.28	61	

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE V (Continued)

Test Data for Super A-286

Test Temperature 1100°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
CG 7419 AK	0.25	88.0	22.0	110.0	120.20	25,960	2.47
7420	0.25	92.0	23.0	115.0	39.01	8,426	3.25
7432	0.25	97.6	24.4	122.0	10.57	2,283	4.75
7418	0.25	104.0	26.0	130.0	1.22	263	
7431	0.25	104.0	26.0	130.0	0.23	50	T.S.
CG 7567 AM	0.25	64.0	16.0	80.0	111.93	24,170	T.S.
7583	0.25	72.0	18.0	90.0	121.16	26,170	T.S.
7616	0.25	76.0	19.0	95.0	15.00	3,240	
7567	0.25	76.0	19.0	95.0	0.30	65	P.S.
7653	0.25	79.2	19.8	99.0	1.67	360	
7583	0.25	80.0	20.0	100.0	0.13	29	P.S.
7656	0.25	82.0	20.5	102.5	0.36	78	
CG 7493 AK	0	90.0	0	90.0	98.72		
7507	0	100.0	0	100.0	39.20		
7449	0	110.0	0	110.0	20.33		
7480	0	125.0	0	125.0	2.33		
CG 7674 AM	0	102.5	0	102.5	139.79		T.S.
7668	0	110.0	0	110.0	138.99		T.S.
7590	0	115.0	0	115.0	166.72		T.S.
7659	0	122.5	0	122.5	93.47		T.S.
7584	0	130.0	0	130.0	23.50		
7669	0	140.0	0	140.0	14.62		
7614	0	140.0	0	140.0	6.39		
7590	0	150.0	0	150.0	3.91		P.S.
7682	0	160.0	0	160.0	3.37		
7659	0	180.0	0	180.0	0.17		P.S.
7676	0	190.0	0	190.0	0.40		

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE V (Continued)

Test Data for Super A-286

Test Temperature 1250°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
CG 7527 AK	∞	0	44.0	44.0	106.64	23,030	
7566	∞	0	47.0	47.0	5.68	1,227	
7520	∞	0	48.0	48.0	8.43	1,821	
7460	∞	0	52.0	52.0	1.26	272	P.S.
7564	∞	0	54.0	54.0	0.56	121	
CG 7599 AM	∞	0	30.0	30.0	159.84	34,520	T.S.
7599	∞	0	33.0	33.0	1.42	306	P.S.
7631	∞	0	34.0	34.0	119.00	25,700	T.S.
7609	∞	0	35.0	35.0	119.97	25,910	T.S.
7615	∞	0	36.0	36.0	0.35	76	
7609	∞	0	37.5	37.5	1.28	276	P.S.
7625	∞	0	37.5	37.5	0.22	47	
7618	∞	0	40.0	40.0	0.13	29	
CG 7450 AK	1.5	26.0	39.0	65.0	132.55	28,630	T.S.
7459	1.5	28.0	42.0	70.0	91.33	19,730	0.32
7435	1.5	28.8	43.2	72.0	25.70	5,557	
7422	1.5	30.0	45.0	75.0	10.14	2,190	0.25
7423	1.5	32.0	48.0	80.0	4.41	953	0.53
7452	1.5	35.0	52.5	87.5	1.25	270	
CG 7568 AM	1.5	15.2	22.8	38.0	116.47	25,120	T.S.
7620	1.5	16.0	24.0	40.0	120.15	25,960	T.S.
7594	1.5	16.8	25.2	42.0	0.74	161	
7596	1.5	16.8	25.2	42.0	0.57	123	
7611	1.5	18.0	27.0	45.0	0.21	45	
CG 7457 AK	0.67	46.5	31.0	77.5	116.80	25,230	2.57
7467	0.67	51.0	34.0	85.0	45.43	9,813	2.15
7477	0.67	54.0	36.0	90.0	18.38	3,969	2.43
7478	0.67	57.0	38.0	95.0	5.92	1,279	2.05
7429	0.67	61.5	41.0	102.5	3.55	767	P.S.

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE V (continued)

Test Data for Super A-286

Test Temperature 1250°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
CG 7604 AM	0.67	27.0	18.0	45.0	215.52	46,550	T.S.
7577	0.67	28.8	19.2	48.0	190.50	41,150	T.S.
7595	0.67	31.2	20.8	52.0	7.02	1,516	
7574	0.67	33.0	22.0	55.0	0.25	54	
CG 7543 AK	0	60.0	0	60.0	95.20		14.79
7426	0	65.0	0	65.0	22.90		22.90 P.S.
7536	0	70.0	0	70.0	14.82		14.80
7444	0	87.5	0	87.5	1.32		P.S.
CG 7605 AM	0	80.0	0	80.0	129.11		
7602	0	87.5	0	87.5	61.48		
7606	0	95.0	0	95.0	10.25		
7598	0	105.0	0	105.0	6.02		
7592	0	120.0	0	120.0	1.48		

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE VI

Test Data for Super A-286 (0.2% Creep)

Test Temperature 1000°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	Stress, KSI S_c	Total Time Hours	Total Time Kilocycles	Time to 0.2% Creep	Total Creep	
CG 7488 AK	0.35	80.0	28.0	108.0	119.00	25,700		0.18	T.S.
7492	0.35	81.1	28.4	109.5	78.00	16,800		0.16	T.S.
7513	0.35	81.5	28.5	110.0	91.10	19,800	78.00	0.21	T.S.
7506	0.35	82.2	28.8	111.0	113.67	24,500		0.15	T.S.
7451	0.35	82.2	28.8	111.0	50.00	10,800	20.00	0.23	T.S.
7512	0.35	82.2	28.8	111.0	20.00	4,320	2.80	0.27	T.S.
7514	0.35	83.3	29.2	112.5	118.90	25,700	54.50	0.24	T.S.
7540	0.35	83.3	29.2	112.5	21.00	4,540	16.00	0.22	T.S.
CG 7436 AK	0.15	89.6	13.4	103.0	190.00	41,000	120.00	0.21	T.S.
7469	0.15	91.3	13.7	105.0	114.60	24,800	47.50	0.23	T.S.
7434	0.15	92.5	13.9	106.4	63.00	13,600	6.00	0.28	T.S.
7465	0.15	93.2	14.0	107.2	65.5	14,150	12.50	0.31	T.S.
7553	0.15	93.7	14.0	107.7	24.00	5,200	2.50	0.26	T.S.
7464	0.15	93.9	14.1	108.0	0.92	198	0.01	0.29	T.S.
7462	0.15	96.0	14.4	110.4	39.17	8,450	2.50	0.32	T.S.

Test Temperature 1100°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	Stress, KSI S_c	Total Time Hours	Total Time Kilocycles	Time to 0.2% Creep	Total Creep	
CG 7415 AK	0.25	72.0	18.0	90.0	95.78	21,100	85.00	0.21	T.S.
7417	0.25	75.2	18.8	94.0	89.03	19,200		0.18	T.S.
7453	0.25	75.2	18.8	94.0	69.00	14,900	10.0	0.30	T.S.
7428	0.25	77.6	19.4	97.0	93.00	20,100	21.0	0.32	T.S.
7429	0.25	73.4	19.6	98.0	65.36	14,100		0.19	T.S.
7442	0.25	80.0	20.0	100.0	17.00	3,680		0.19	T.S.
7458	0.25	84.0	81.0	105.0	1.17	252	0.80	0.22	T.S.

T.S. - Test Stopped

TABLE VI (Continued)

Test Data for Super A-286 (0.2% Creep)

Test Temperature 1100°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Total Time Hours	Kilocycles	Time to 0.2% Creep	Total Creep	
CG 7509 AK	0.10	78.2	7.8	86.0	118.30	25,600	48.00	0.30	T.S.
7519	0.10	80.0	8.0	88.0	95.60	20,600	31.00	0.32	T.S.
7489	0.10	81.8	8.2	90.0	162.00	35,000	85.00	0.28	T.S.
7490	0.10	81.8	8.2	90.0	50.65	10,900	13.00	0.30	T.S.
7481	0.10	86.4	8.6	95.0	14.13	3,060	10.15	0.22	T.S.
7482	0.10	90.9	9.1	100.0	16.15	3,450	2.30	0.39	T.S.
7491	0.10	90.9	9.1	100.0	0.80	173	0.47	0.23	T.S.
7529	0.10	95.5	9.5	105.0	3.07	663	1.70	0.26	T.S.

Test Temperature 1250°F

Specimen Number	Ratio A	Applied S_m	Stress, KSI S_a	S_c	Total Time Hours	Kilocycles	Time to 0.2% Creep	Total Creep	
CG 7438 AK	1.5	27.6	41.4	69.0	41.37	8,940	25.00	0.27	T.S.
7459	1.5	28.0	42.0	70.0	91.5	19,800	55.80	0.33	T.S.
7454	1.5	30.0	45.0	75.0	8.66	1,870	1.50	0.29	T.S.
7427	1.5	32.0	48.0	80.0	3.10	670	2.36	0.24	T.S.
7433	1.5	32.0	48.0	80.0	1.60	346	1.32	0.32	T.S.
7455	1.5	32.0	48.0	80.0	0.50	108	0.28	0.28	T.S.
CG 7465 AK	0.67	30.0	20.0	50.0	112.00	24,200	82.50	0.24	T.S.
7473	0.67	33.0	27.0	55.0	94.00	20,300	36.00	0.28	T.S.
7471	0.67	36.0	24.0	60.0	86.50	18,700	19.50	0.47	T.S.
7460	0.67	42.0	28.0	70.0	2.92	627		0.12	T.S.
7474	0.67	46.5	31.0	77.5	4.75	1,030	2.50	0.23	T.S.
7463	0.67	46.5	31.0	77.5	1.31	283		0.18	T.S.

T.S. - Test Stopped

TABLE VII

Tensile Test Data for Inconel 718 Sheet

Test Temp	Orien-tation	UTS	0.2% YTS	Elong	AR	E
(°F)		(ksi)	(ksi)	(%)	(%)	(10^6psi)
75	T	196.0	163.3	---	---	28.7 *
75	T	198.9	164.7	20.8	27.8	26.5
75	L	195.8	166.8	16.5	29.5	29.3
75	L	195.8	162.4	---	---	29.2 *
1000	T	165.3	141.8	15.2	32.8	29.9
1000	T	164.9	141.8	19.5	33.8	25.6
1000	L	163.7	142.5	21.5	51.8	20.6
1000	L	164.8	144.3	23.2	48.7	28.1
1000	L	162.3	141.4	18.3	36.1	24.3
1200	T	165.1	135.2	16.2	20.6	22.5
1200	T	157.9	132.0	6.5	16.4	19.0
1200	T	155.6	135.6	9.4	14.9	21.9
1200	L	159.9	135.0	10.8	17.1	23.6
1200	L	158.7	136.1	12.8	22.1	22.3
1400	T	112.7	101.6	8.8	9.5	20.9
1400	T	113.2	99.5	9.0	8.5	20.0
1400	L	120.7	104.2	4.2	10.5	19.6
1400	L	114.8	101.3	3.6	9.8	19.2

* ——— Fracture Under Knife Edge
T ——— Transverse Orientation
L ——— Longitudinal Orientation

TABLE VIII

Test Data for Inconel 718 Sheet

Test Temperature 75°F

Specimen Number	K_t	Orient-ation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8965	1.0	T	∞	0	38.0	38.0	161.83	34.960	T.S.
9020			∞	0	40.0	40.0	165.57	35.[illegible]00	T.S.
9032			∞	0	42.5	42.5	13.78	2.976	
8914			∞	0	45.0	45.0	13.25	2.862	
8963			∞	0	45.0	45.0	136.85	29.560	
9024			∞	0	47.5	47.5	5.82	1.257	
8998			∞	0	50.0	50.0	2.32	501	
8921			∞	0	50.0	50.0	2.43	525	
8904			∞	0	50.0	50.0	4.80	1,037	
8913			∞	0	55.0	55.0	2.22	480	
8932			∞	0	60.0	60.0	1.60	346	
8999			∞	0	75.0	75.0	0.11	24	
9072		L	∞	0	45.0	45.0	139.75	30.180	T.S.
8861				0	60.0	60.0	1.05	227	
8948	3.0	T	∞	0	20.0	20.0	137.94	29.800	T.S.
8879			∞	0	21.0	21.0	138.37	29.890	T.S.
8868			∞	0	22.0	22.0	41.65	8.996	
8916			∞	0	22.0	22.0	41.74	9.01[illegible]	
8896			∞	0	23.5	23.5	2.95	63[illegible]	
8900			∞	0	23.5	23.5	3.28	70[illegible]	
8629			∞	0	23.5	23.5	3.93	8[illegible]	
8933			∞	0	25.0	25.0	4.47	9[illegible]	
8941			∞	0	30.0	30.0	1.42	3[illegible]	
8843		L	∞	0	25.0	25.0	5.51	1.1[illegible]	
8991	1.0	T	0.67	39.0	26.0	65.0	142.44	30.770	T.S.
8869			0.67	43.2	28.8	72.0	167.15	36.100	T.S.
8535			0.67	45.0	30.0	75.0	163.63	35.340	T.S.
8653			0.67	48.0	32.0	80.0	2.23	482	
8536			0.67	48.0	32.0	80.0	4.39	948	
8566			0.67	51.0	34.0	85.0	1.63	352	
8613			0.67	54.0	36.0	90.0	2.23	482	
8906			0.67	57.0	38.0	95.0	1.85	400	
8898			0.67	63.0	42.0	105.0	1.80	389	
8677			0.67	72.0	48.0	120.0	0.68	147	

T.S. - Test Stopped

TABLE VIII (Continued)

Test Data for Inconel 718 Sheet

Test Temperature 75°F

Specimen Number	K_t	Orientation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8573	3.0	T	0.67	21.0	14.0	35.0	142.0	30.670	T.S.
8561			0.67	22.5	15.0	37.5	73.78	15.940	
8637			0.67	24.0	16.0	40.0	34.34	7.417	
8912			0.67	28.5	19.0	47.5	1.15	248	
8651			0.67	28.5	19.0	47.5	2.72	587	
8565			0.67	33.0	22.0	55.0	1.12	242	
8571			0.67	39.0	26.0	65.0	0.38	82	
8674			0.67	54.0	36.0	90.0	0.15	32	
8527	1.0	T	0	185.0	0	185.0	140		0.90T.S.
8634			0	195.0	0	195.0	140		1.46T.S.
8642			0	198.0	0	198.0	145.0		3.55T.S.
8604			0	201.0	0	201.0	0		F.L.
8593			0	205.0	0	205.0	0		F.L.
8831		L	0	198.0	0	198.0	186.0		T.S.
8866			0	201.0	0	201.0	118.12		T.S.
8924	3.0	T	0	210.0	0	210.0	162.22		T.S.
8937			0	216.0	0	216.0	91.0		
8955			0	218.0	0	218.0	0.071		
8880			0	220.0	0	220.0	0		
8577			0	220.0	0	220.0	140.3		T.S.
8883			0	222.0	0	222.0	~0		
8479		L	0	210.0	0	210.0	149.13		T.S.
8829			0	213.0	0	213.0	168.76		T.S.
8498			0	216.0	0	216.0	0		
8842			0	217.0	0	217.0	0		
Test Temperature 1000°F									
8669	1.0	T	∞	0	55.0	55.0	111.30	24.040	T.S.
8664			∞	0	58.0	58.0	15.96	3.447	
8978			∞	0	60.0	60.0	11.29	2.439	
8878			∞	0	65.0	65.0	1.34	289	
8935			∞	0	70.0	70.0	0.04	9	
8886			∞	0	70.0	70.0	1.72	372	
8481		L	∞	0	52.5	52.5	8.09	1.747	
8839			∞	0	60.0	60.0	0.5	108	

T.S. - Test Stopped

F.L. - Failed Before Full Load

TABLE VIII (Continued)

Test Data for Inconel 718 Sheet

Test Temperature 1000°F

Specimen Number	K_t	Orient-ation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8668	3.0	T	∞	0	18.0	18.0	112.35	24.270	T.S.
8595			∞	0	20.0	20.0	114.21	24.670	T.S.
8657			∞	0	23.0	23.0	0.93	201	
8612			∞	0	23.0	23.0	2.81	607	
8589			∞	0	27.5	27.5	0.70	151	
8557			∞	0	35.0	35.0	0.23	50	
8531			∞	0	40.0	40.0	0.12	26	
8558			∞	0	45.0	45.0	0.07	14	
8492		L	∞	0	25.0	25.0	0.7	151	
8945	1.0	T	1.0	42.5	42.5	85.0	116.30	25.120	T.S.
8940			1.0	45.0	45.0	90.0	65.16	14.070	
8885			1.0	47.5	47.5	95.0	3.59	775	
8656			1.0	50.0	50.0	100.0	2.11	456	
8903			1.	52.5	52.5	105.0	1.62	349	
8485		L	1.0	45.0	45.0	90.0	7.68	1.659	
8652	3.0	T	1.0	20.0	20.0	40.0	136.66	29.520	T.S.
8635			1.0	21.5	21.5	43.0	4.32	933	
8645			1.0	22.5	22.5	45.0	8.84	1.909	
8525			1.0	23.5	23.5	47.0	1.85	400	
8517			1.0	25.0	25.0	50.0	0.35	76	
8490		L	1.0	21.0	21.0	42.0	0.73	158	
8495			1.0	22.5	22.5	45.0	0.42	91	
8496			1.0	22.5	22.5	45.0	0.69	149	
8494			1.0	22.5	22.5	45.0	0.96	207	
8875	1.0	T	0.67	57.0	38.0	95.0	138.26	29.860	T.S.
8608			0.67	59.9	40.1	100.0	105.51	22.790	
8544			0.67	61.5	41.0	102.5	5.62	1.214	
8548			0.67	63.0	42.0	105.0	3.93	849	
8977			0.67	63.0	42.0	105.0	21.46	4.636	
8584			0.67	67.5	45.0	112.5	1.87	403	
8532			0.67	72.0	48.0	120.0	1.34	290	

T.S. - Test Stopped

TABLE VIII (Continued)

Test Data for Inconel 718 Sheet

Test Temperature 1000°F

Specimen Number	K_t	Orientation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8516	3.0	T	0.67	21.0	14.0	35.0	113.50	24.520	T.S.
8600			0.67	25.5	17.0	42.5	139.69	30.170	T.S.
8641			0.67	27.6	18.4	46.0	163.0	35.210	T.S.
8983			0.67	30.0	20.0	50.0	0.97	210	
8960			0.67	30.0	20.0	50.0	1.15	248	
8547			0.67	30.0	20.0	50.0	2.22	480	
8514			0.67	39.0	26.0	65.0	0.30	65	
8578			0.67	39.0	26.0	65.0	0.31	67	
8515			0.67	45.0	30.0	75.0	0.20	43	
8601			0.67	51.0	34.0	85.0	0.09	19	
8523			0.67	54.0	36.0	90.0	0.07	15	
8647	1.0	T	0.25	116.0	29.0	145.0	111.68	24.120	T.S.
8574			0.25	20.0	30.0	150.0	48.56	10.490	
8597			0.25	124.0	31.0	155.0	20.96	4.527	
8555			0.25	126.0	31.5	157.5	39.6	8.554	
8607			0.25	12 .0	32.0	160.0	13.37	2.888	
8631			0.25	132.0	33.0	165.0	6.16	1.331	
8542			0.25	136.0	34.0	170.0	1.30	381	
8874	3.0	T	0.10	110.0	11.0	121.0	160.90	35.760	T.S.
8992			0.10	122.7	12.3	135.0	185.13	39.990	
8949			0.10	130.0	13.0	143.0	152.14	32.860	
9002			0.10	140.0	14.0	154.0	42.35	9.148	
9000			0.10	145.5	14.5	160.0	11.67	2.521	
9007			0.10	150.0	15.0	165.0	0.95	205	
8539	1.0	T	0	135.0	0	135.0	163.30		0.39 T.S.
8624			0	150.0	0	150.0	114.52		2.45
8675			0	160.0	0	160.0	38.43		3.35
8526			0	167.5	0	167.5	5.65		4.40
8576			0	168.5	0	168.5	3.20		7.00
8618			0	170.0	0	170.0	0		F.L.
8501		L	0	135.0	0	135.0	156.2		0.64
8504			0	140.0	0	140.0	72.6		0.67
8506			0	150.0	0	150.0	53.0		3.17
8500			0	160.0	0	160.0	14.1		4.12
8509			0	167.5	0	167.5	3.83		6.50

T. S. - Test Stopped

F. L. - Failed Before Full Load

TABLE VIII (Continued)

Test Data for Inconel 718 Sheet

Test Temperature 1000°F

Specimen Number	K_t	Orient-ation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8545	3.0	T	0	150.0	0	150.0	131.13		
8522			0	155.0	0	155.0	86.62		
8976			0	160.0	0	160.0	62.42		
8520			0	160.0	0	160.0	75.35		
8529			0	170.0	0	170.0	33.2		
8528			0	180.0	0	180.0	8.5		
8521			0	181.5	0	181.5	7.9		
8534			0	183.0	0	183.0	0		F.L.
8611			0	187.5	0	187.5	0		F.L.
8533			0	190.0	0	190.0	0		F.L.
8491		L	0	160.0	0	160.0	33.92		
8847			0	170.0	0	170.0	52.92		
8497			0	180.0	0	180.0	4.65		

Test Temperature 1200°F

Specimen Number	K_t	Orient-ation	Ratio A	S_m	S_a	S_c	Hours	Kilocycles	Strain %
8980	1.0	T	∞	0	47.5	47.5	136.25	29.430	T.S.
8961			∞	0	49.0	49.0	25.42	5.491	
9019			∞	0	50.0	50.0	1.59	343	
9001			∞	0	52.5	52.5	0.95	205	
8967			∞	0	55.0	55.0	0.08	17	
8952			∞	0	62.5	62.5	0.02	4	
8979			∞	0	65.0	65.0	0.01	2	
8859		L	∞	0	55.0	55.0	0.07	14	
8570	3.0	T	∞	0	20.0	20.0	121.50	26.240	T.S.
8995			∞	0	21.0	21.0	107.63	23.250	
8953			∞	0	22.5	22.5	1.08	233	
8986			∞	0	25.0	25.0	0.60	130	
9035	1.0	T	1.0	42.5	42.5	85.0	135.71	29.250	T.S.
8908			1.0	45.0	45.0	90.0	12.05	2.603	
8931			1.0	47.5	47.5	95.0	4.36	942	
9023			1.0	50.0	50.0	100.0	1.23	266	
9022			1.0	52.5	52.5	105.0	0.42	91	

T. S. - Test Stopped

F. L. - Failed Before Full Load

TABLE VIII (Continued)

Test Data for Inconel 718 Sheet

Test Temperature 1200°F

Specimen Number	K_t	Orientation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8920	3.0	T	1.0	16.5	16.5	33.0	117.02	25.280	T.S.
8946			1.0	17.5	17.5	35.0	83.77	18.090	
8968			1.0	18.5	18.5	37.0	42.61	9.204	
8917			1.0	18.75	18.75	37.5	3.05	659	
9026			1.0	20.0	20.0	40.0	1.94	419	
8887			1.0	21.25	21.25	42.5	0.62	133	
8543	1.0	T	0	87.5	0	87.5	117.82		0.96
8581			0	100.0	0	100.0	31.43		1.46
8546			0	110.0	0	110.0	9.60		1.61
8621			0	120.0	0	120.0	3.10		2.49
8585			0	135.0	0	135.0	0.87		3.30
8930	3.0	T	0	85.0	0	85.0	28.03		
8956			0	85.0	0	85.0	73.45		
8951			0	100.0	0	100.0	19.0		
8975			0	120.0	0	120.0	2.61		
8936			0	135.0	0	135.0	0.67		

Test Temperature 1400°F

Specimen Number	K_t	Orientation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8643	1.0	T	∞	0	35.0	35.0	113.88	24.600	T.S.
8568			∞	0	38.0	38.0	28.56	6.169	
8628			∞	0	38.0	38.0	121.06	26.150	T.S.
8934			∞	0	40.0	40.0	74.79	16.150	
8894			∞	0	42.0	42.0	4.03	871	
8950			∞	0	42.0	42.0	35.23	7.610	
8659			∞	0	42.5	42.5	8.31	1.795	
8938			∞	0	42.5	42.5	58.18	12.570	
9036			∞	0	44.0	44.0	0.04	9	
8660			∞	0	45.0	45.0	0.07	14	
8553			∞	0	45.0	45.0	55.53	12.000	
8973			∞	0	45.0	45.0	69.69	15.060	
8918			∞	0	46.0	46.0	0.19	41	
8884			∞	0	7.0	47.0	0.32	68	
8947			∞	0	47.5	47.5	0	0	F. L.
8909			∞	0	48.0	48.0	0.04	9	
8644			∞	0	48.0	48.0	0.60	130	
8922			∞	0	55.0	55.0	0	0	F. L.
8864		L	∞	0	38.0	38.0	34.83	7.530	

T.S. - Test Stopped

F.L. - Failed Before Full Load

TABLE VIII (Continued)

Test Data for Inconel 718 Sheet

Test Temperature 1400°F

Specimen Number	K_t	Orientation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8988	3.0	T	∞	0	17.5	17.5	116.21	25.100	T.S.
8902			∞	0	19.0	19.0	2.38	514	
8962			∞	0	19.0	19.0	25.82	5.577	
8970			∞	0	20.0	20.0	6.87	1.484	
8892			∞	0	21.0	21.0	0.86	186	
9006			∞	0	25.0	25.0	0.17	36	
8486		L	∞	0	19.0	19.0	84.26	18.200	
8482			∞	0	21.0	21.0	0.70	151	
8964	1.0	T	1.5	18.0	27.0	45.0	136.82	29.550	T.S.
8989			1.5	20.0	30.0	50.0	116.56	25.180	T.S.
8901			1.5	21.2	31.8	53.0	38.15	8.240	
8873			1.5	22.0	33.0	55.0	49.90	10.780	
8663			1.5	23.0	34.5	57.5	81.20	17.540	
8996			1.5	25.0	37.5	62.5	8.93	1.929	
8971			1.5	25.0	37.5	62.5	36.86	7.962	
8982			1.5	26.0	39.0	65.0	22.11	4.776	
8907			1.5	26.0	39.0	65.0	25.31	5.467	
9012			1.5	28.0	42.0	70.0	28.03	6.055	
9020			1.5	30.0	45.0	75.0	1.77	382	
8567			1.5	30.0	45.0	75.0	4.26	920	
8893			1.5	31.0	46.5	77.5	1.05	227	
8943			1.5	31.0	46.5	77.5	2.09	452	
8985			1.5	31.0	46.5	77.5	6.54	1.413	
8987			1.5	32.0	48.0	80.0	2.28	493	
9028			1.5	32.0	48.0	80.0	3.05	659	
8575			1.5	35.0	52.5	87.5	0.07	14	
8865		L	1.5	28.0	42.0	70.0	9.87	2.132	
9003	3.0	T	1.5	19.0	13.5	22.5	121.85	26.320	T.S.
8925			1.5	10.0	15.0	25.0	28.60	6.178	
8895			1.5	10.0	15.0	25.0	139.44	30.120	
8926			1.5	11.0	16.5	27.5	17.45	3.779	
8981			1.5	12.0	18.0	30.0	2.46	531	P.S.
9010			1.5	14.0	21.0	35.0	0.77	166	
8480		L	1.5	11.0	16.5	27.5	6.27	1.354	
8484			1.5	12.0	18.0	30.0	3.75	810	

T.S. - Test Stopped
P.S. - Prior Stress History

TABLE VIII (Continued)

Test Data for Inconel 718 Sheet

Test Temperature 1400^{o}F

Specimen Number	K_t	Orient-ation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8627	1.0	T	0.67	30.0	20.0	50.0	123.52	26.680	1.25
8556			0.67	33.0	22.0	55.0	77.62	16.760	0.65
8658			0.67	34.0	26.0	65.0	25.11	5.424	0.51
8671			0.67	42.0	28.0	70.0	13.07	2.823	
8563			0.67	48.0	32.0	80.0	6.73	1.454	0.36
8654			0.67	51.0	34.0	85.0	3.72	804	0.54
8572			0.67	54.0	36.0	90.0	1.84	397	0.56F.P.
8617			0.67	57.0	38.0	95.0	0.91	197	0.34
8594	3.0	T	0.67	15.0	10.0	25.0	163.84	35.390	T.S.
8541			0.67	16.5	11.0	27.5	117.34	25.340	T.S.
8586			0.67	18.0	12.0	30.0	20.82	4.497	
8655			0.67	21.0	14.0	35.0	9.10	1.966	
8670			0.67	22.5	15.0	37.5	1.93	417	
8580			0.67	27.0	18.0	45.0	1.39	300	
8552			0.67	33.0	22.0	55.0	0.50	108	
8622	1.0	T	0.25	36.0	9.0	45.0	122.78	26.500	2.23
8630			0.25	40.0	10.0	50.0	63.1	13.630	1.81
8649			0.25	48.0	12.0	60.0	11.58	2.502	
8678			0.25	48.0	12.0	60.0	17.54	3.789	1.33
8676			0.25	48.0	12.0	60.0	17.79	3.843	
8673			0.25	56.0	14.0	70.0	5.63	1.216	1.05
8667			0.25	64.0	16.0	80.0	1.75	378	1.39
8650			0.25	76.0	19.0	95.0	0.41	88	1.46
8505		L	0.25	36.0	9.0	45.0	86.57	18.700	1.49
8478			0.25	52.0	13.0	65.0	9.07	1.959	1.07
8508			0.25	64.0	16.0	80.0	0.60	130	2.20
8511			0.25	76.0	19.0	95.0	0.42	91	2.10

T.S. - Test Stopped

F.P. - Failed in Pinhole

TABLE VIII (Continued)

Test Data for Inconel 718 Sheet

Test Temperature 1400°F

Specimen Number	K_t	Orient-ation	Ratio A	Applied Stress - KSI S_m	S_a	S_c	Time to Rupture Hours	Kilocycles	Strain %
8915	3.0	T	0.25	40.0	10.0	50.0	10.91	2.357	
8990			0.25	42.8	10.7	53.5	3.88	838	
8905			0.25	44.8	11.2	56.0	2.86	618	
8911			0.25	46.0	11.5	57.5	2.45	529	
9033			0.25	54.0	13.5	67.5	1.31	283	
8882			0.25	56.0	14.0	70.0	1.00	216	
8587	1.0	T	0	37.5	0	37.5	100.30		1.98
8626			0	42.5	0	42.5	48.40		2.17
8625			0	50.0	0	50.0	16.98		1.96
8599			0	60.0	0	60.0	5.40		1.98
8614			0	67.5	0	67.5	2.35		2.92
8610			0	77.5	0	77.5	0.63		3.14
8476		L	0	35.0	0	35.0	135.30		1.48 TS
8513			0	45.0	0	45.0	21.04		1.16
8510			0	60.0	0	60.0	3.85		2.19
8503			0	75.0	0	75.0	0.6		3.08
8665	3.0	T	0	32.0	0	32.0	160.75		
8680			0	35.0	0	35.0	66.67		
8530			0	45.0	0	45.0	15.32		
8439			0	60.0	0	60.0	2.32		
8679			0	75.0	0	75.0	0.42		
8489		L	0	35.0	0	35.0	49.15		
8499			0	60.0	0	60.0	2.00		

T.S. - Test Stopped

L - Longitudinal

K_t = 1.0 Unnotched

K_t = 3.0 Notched

T - Transverse

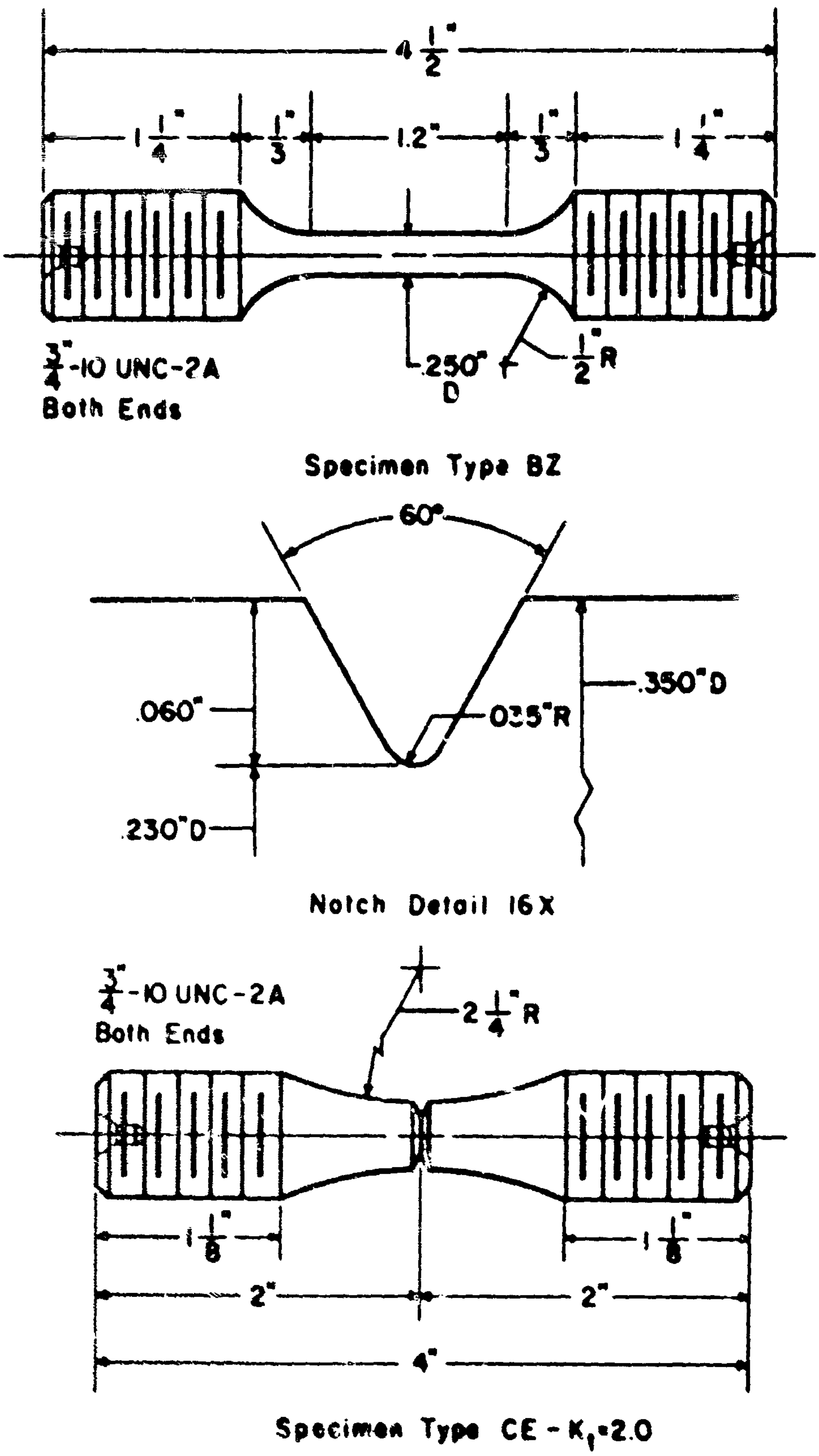
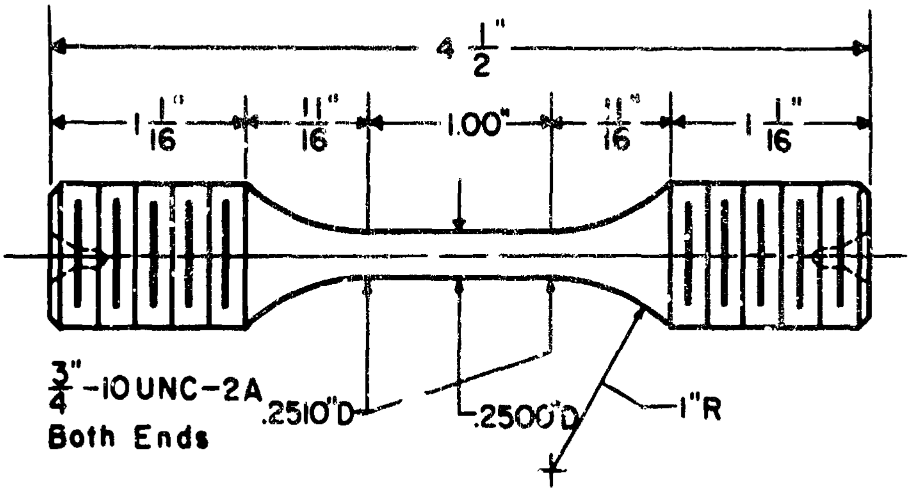
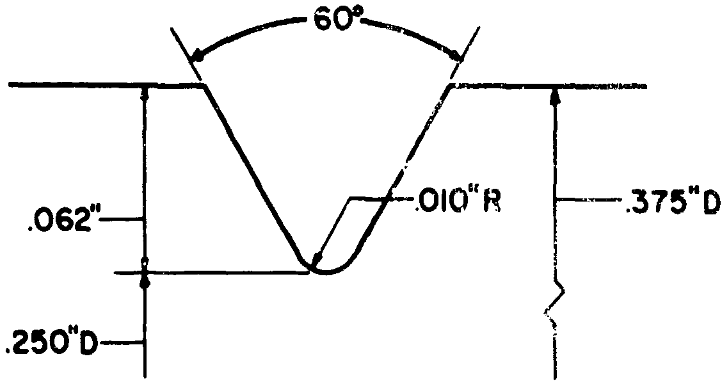


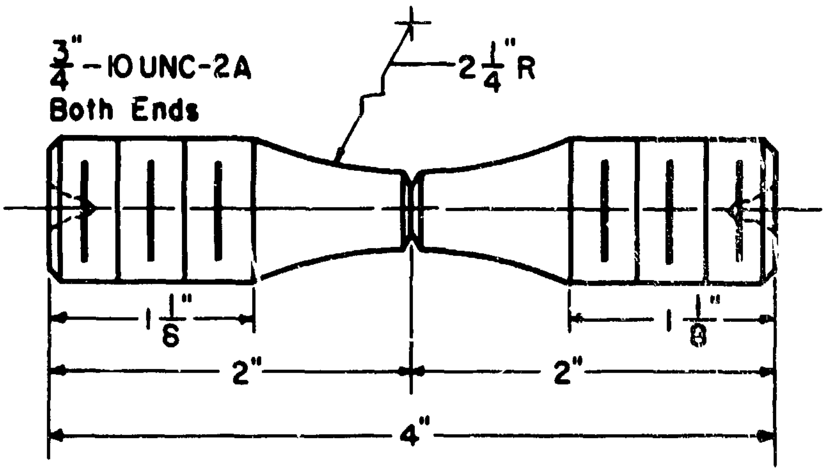
Figure 1 Test Specimens for Nicrotung.



Specimen Type AK



Notch Detail 16X



Specimen Type AM - K_t=3.4

Figure 2 Test Specimens for Super A-286.

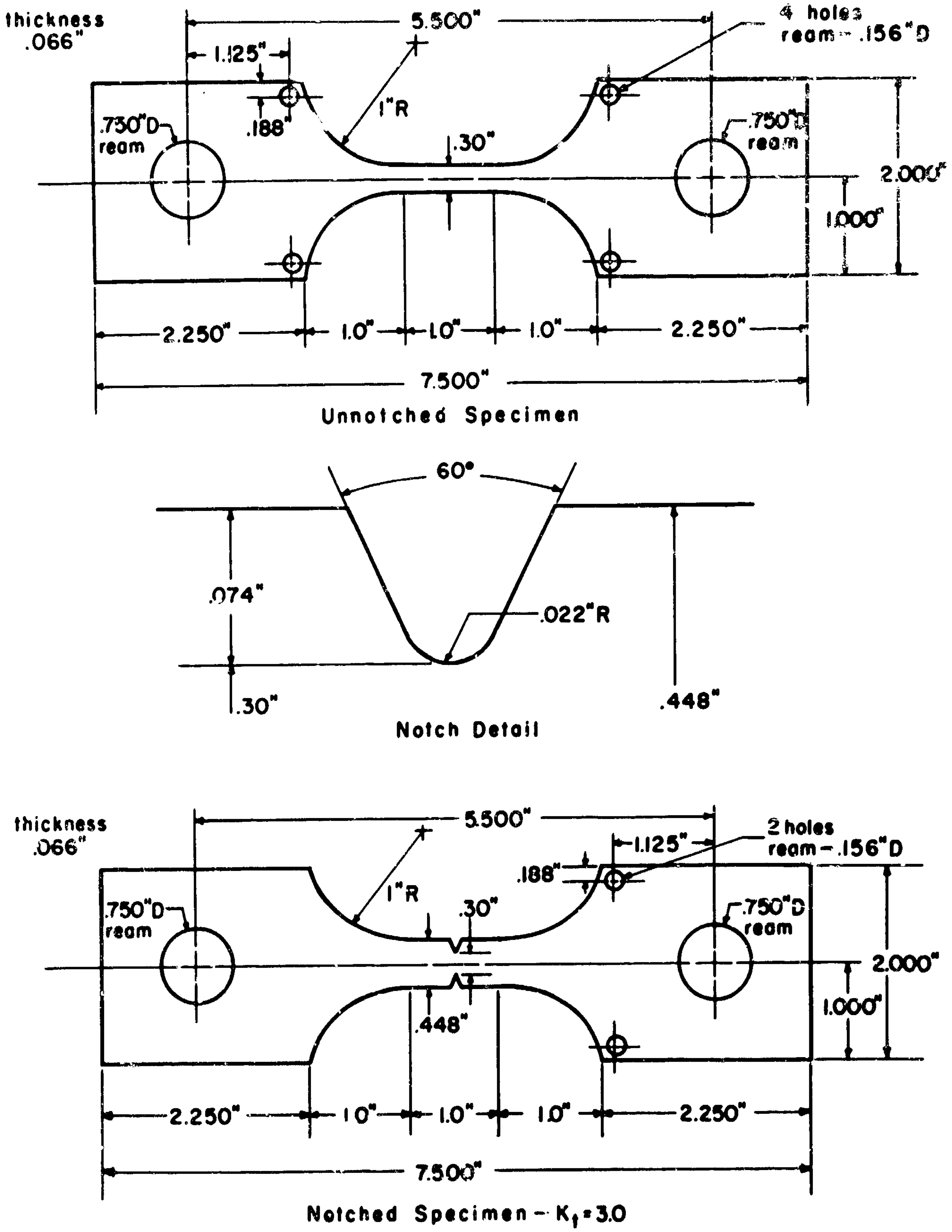


Figure 3 Test Specimens for Inconel 718 Sheet.

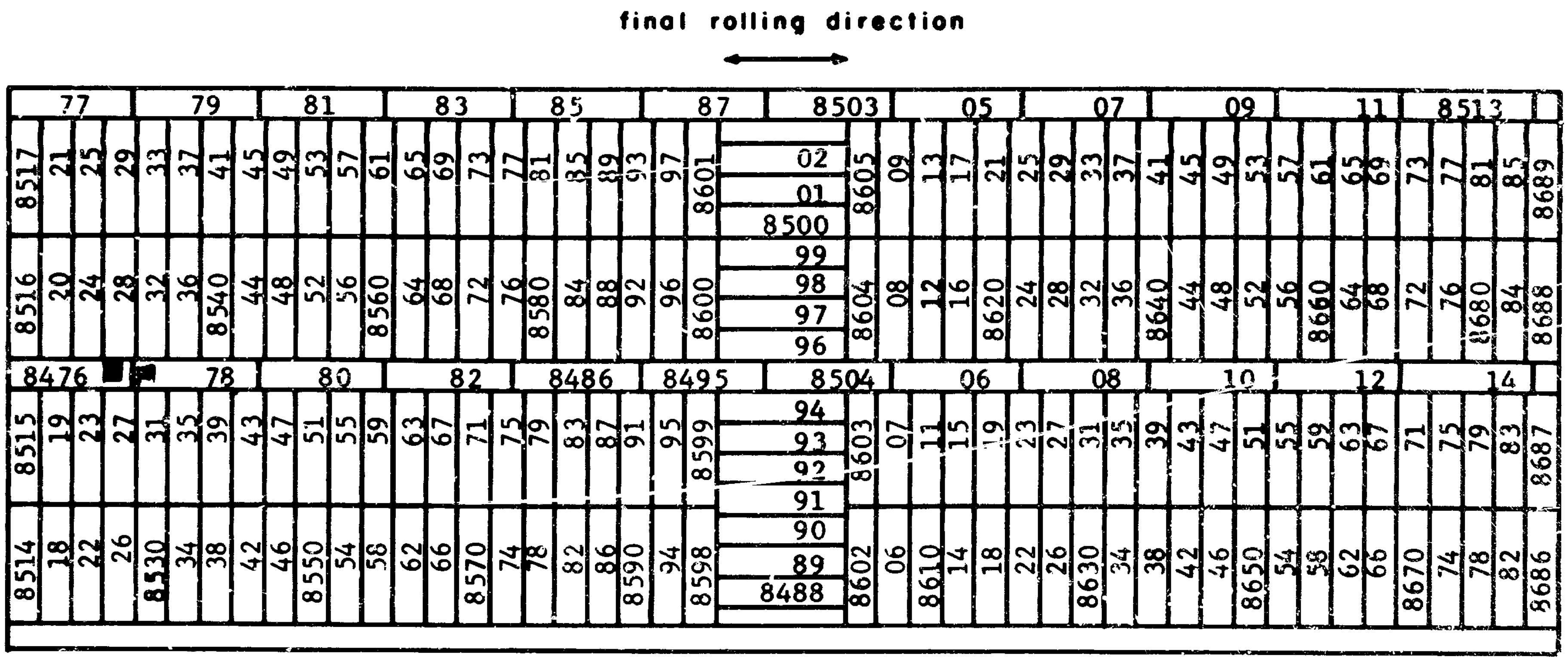


Figure 4 Location of Inconel 718 Specimens in Sheet No. 1.

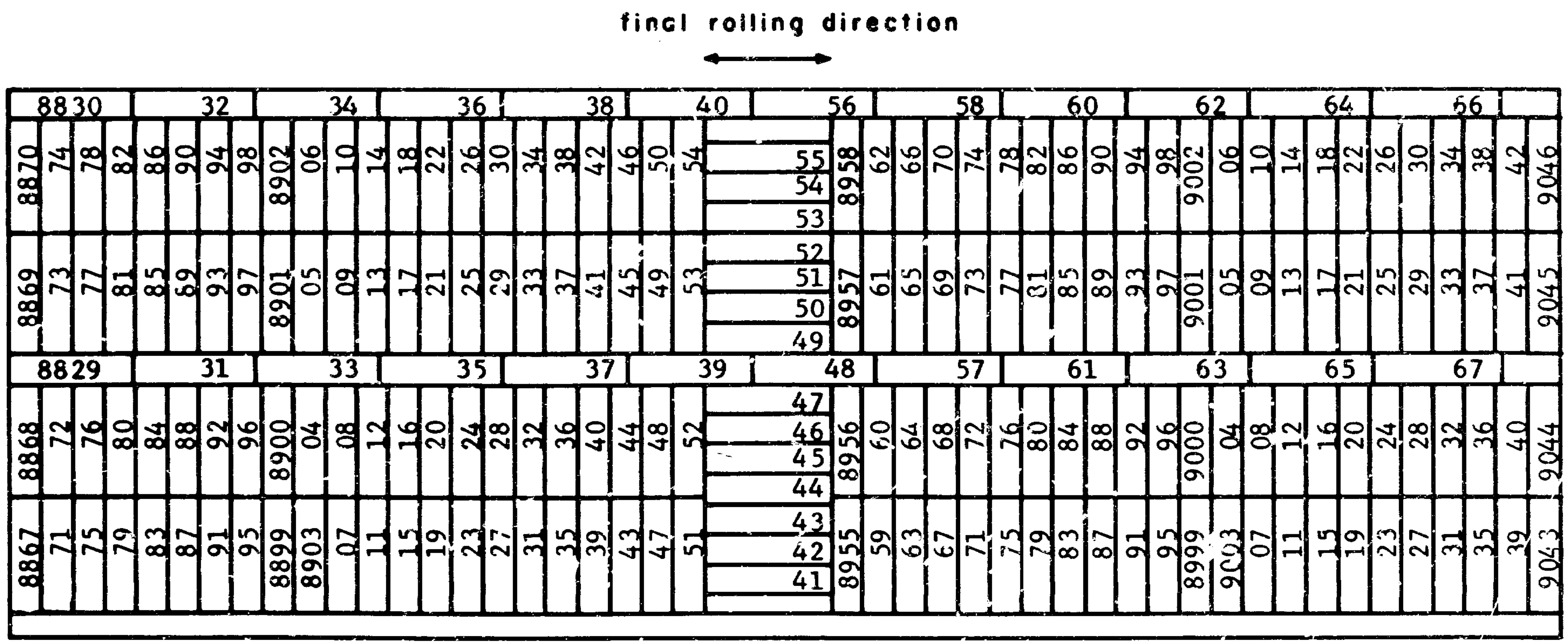


Figure 5 Location of Inconel 718 Specimens in Sheet No. 2.

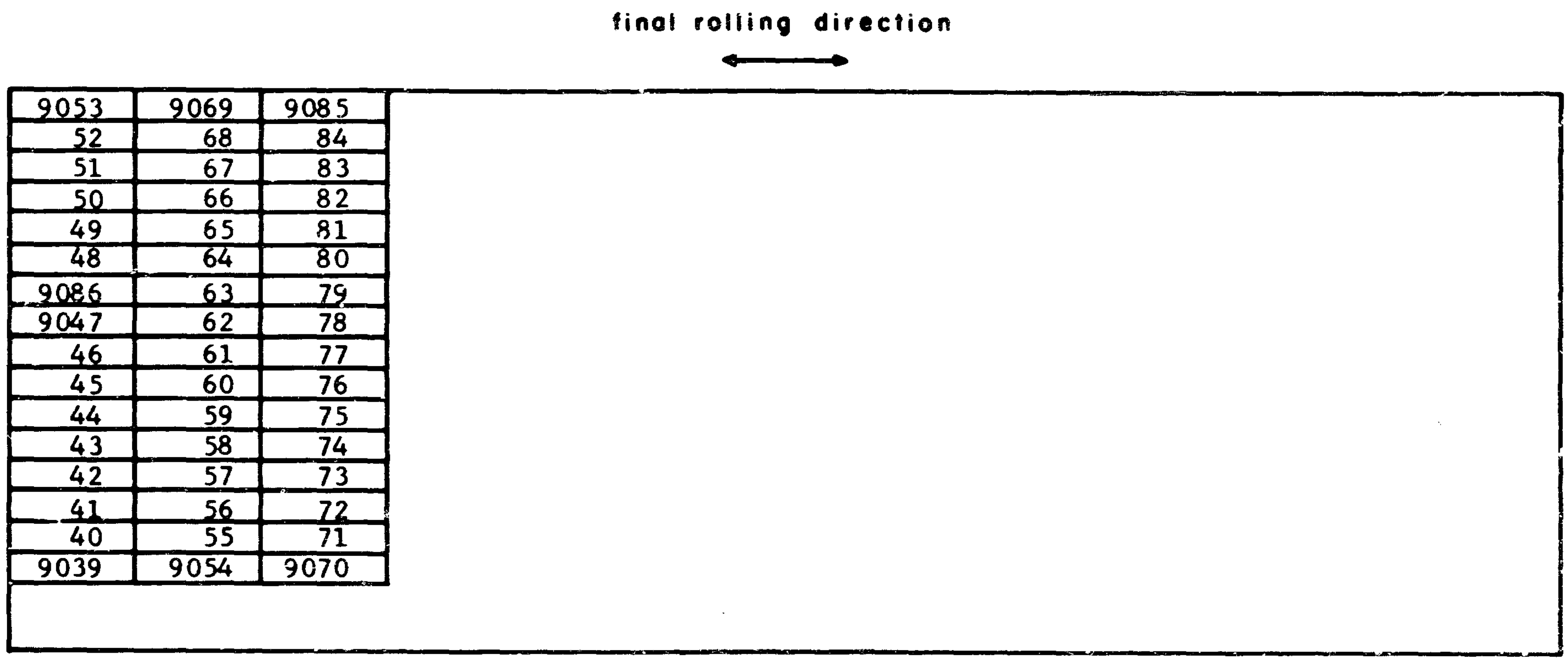


Figure 6 Location of Inconel 718 Specimens in Sheet No. 3.

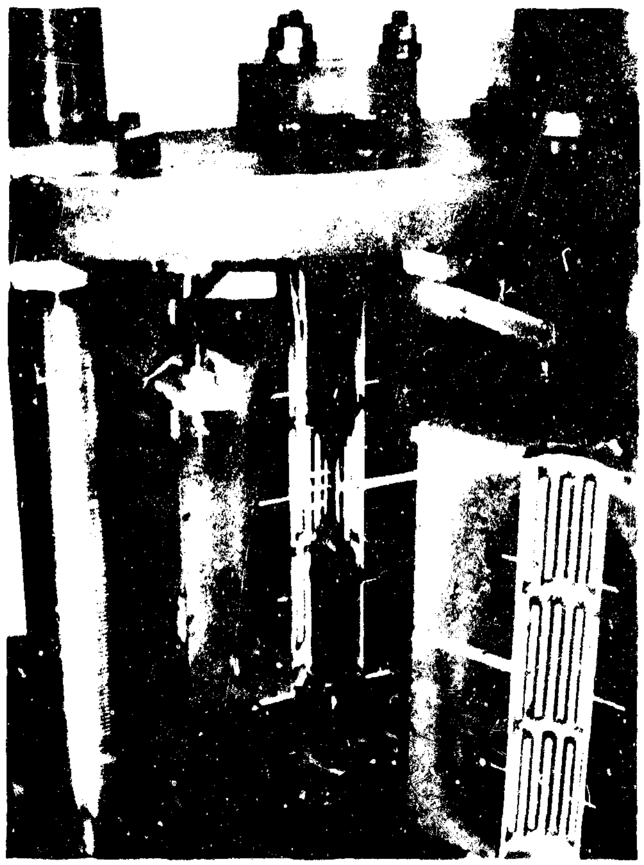


Figure 7 Modified Upper Crosshead of the Testing Machine.

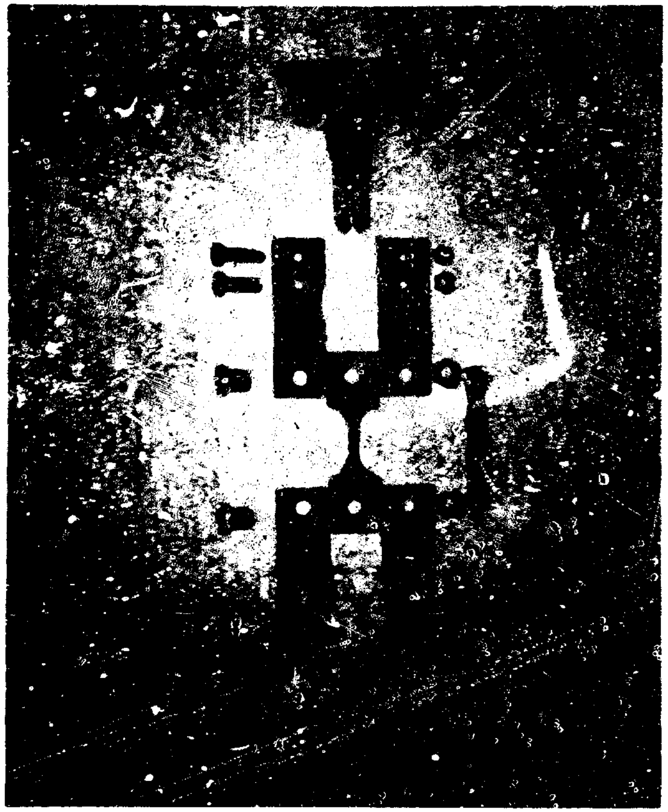


Figure 8 Grip Assembly.

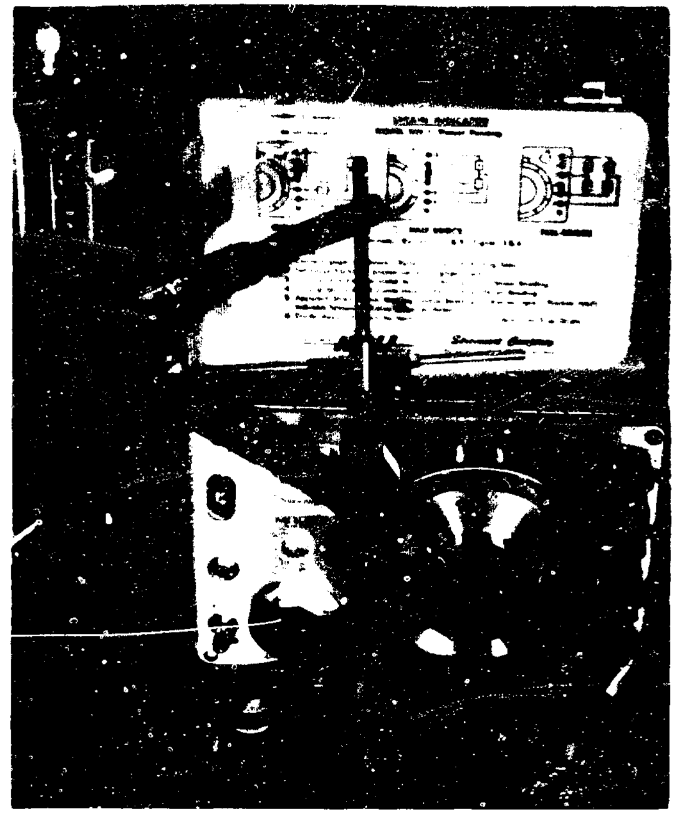


Figure 9 Counter-Torque Wrench.

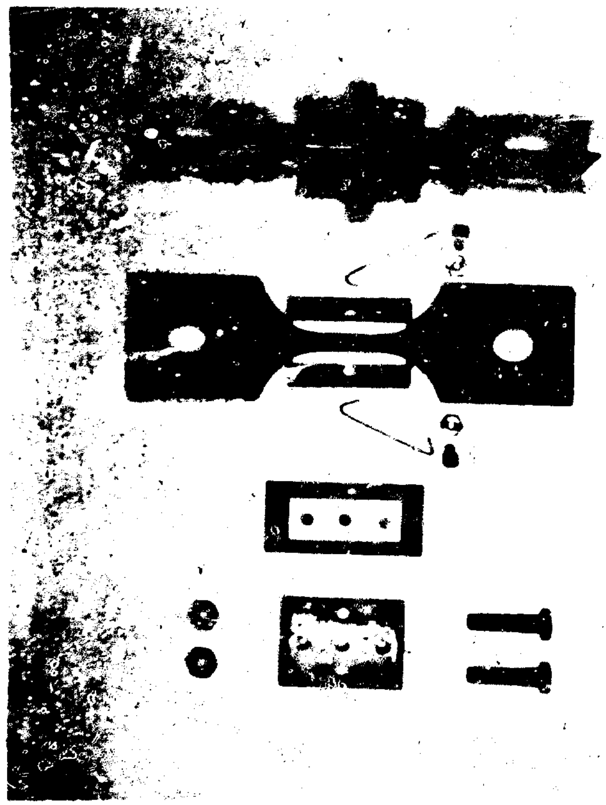


Figure 10 Buckling Restrainer.

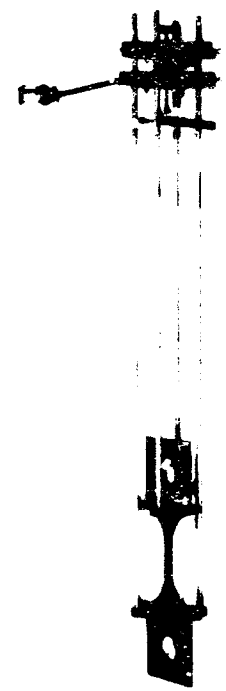


Figure 11 Extensometer.

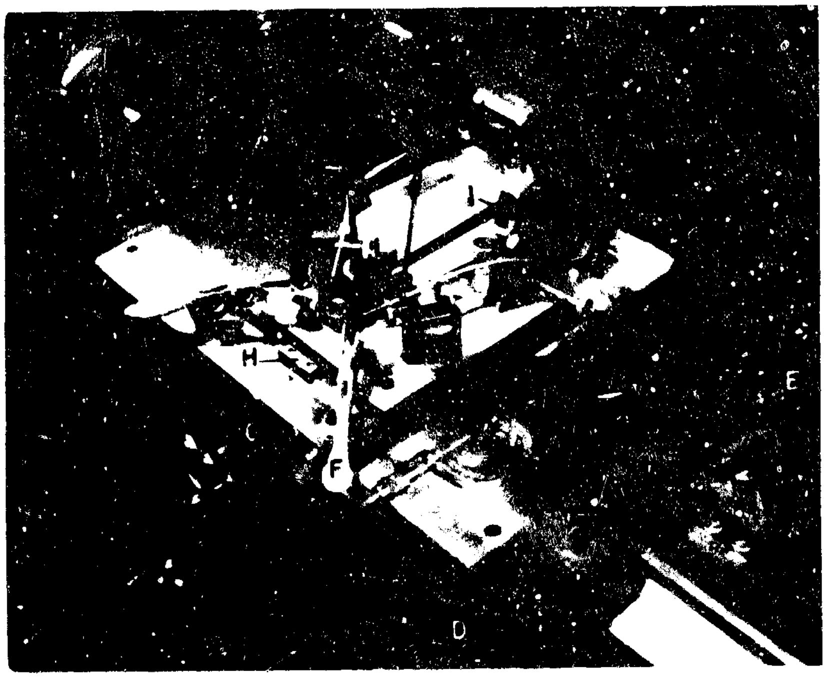


Figure 12 Sheet Specimen Edge Polishing Machine

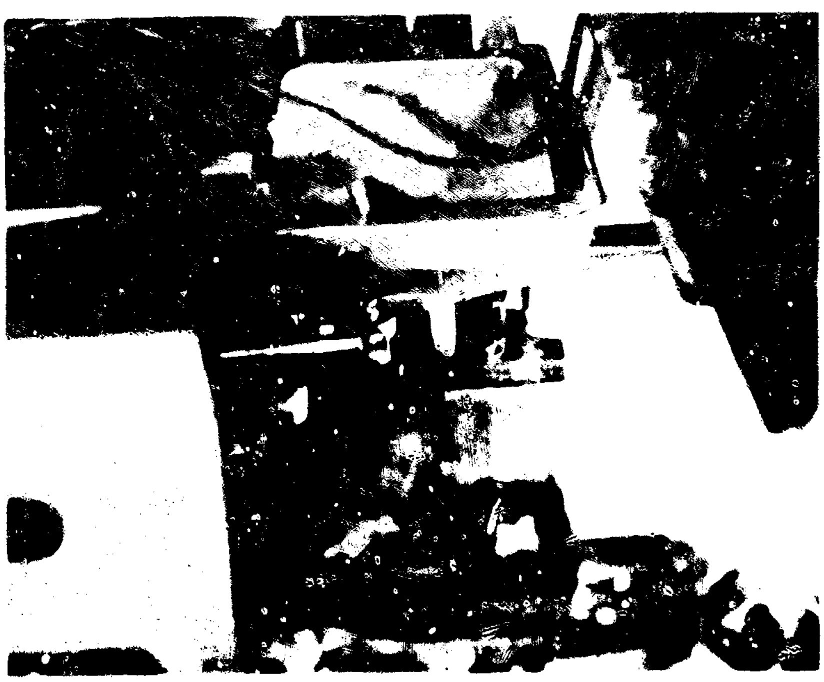


Figure 13 Template and Cam Follower of the Edge Polisher.

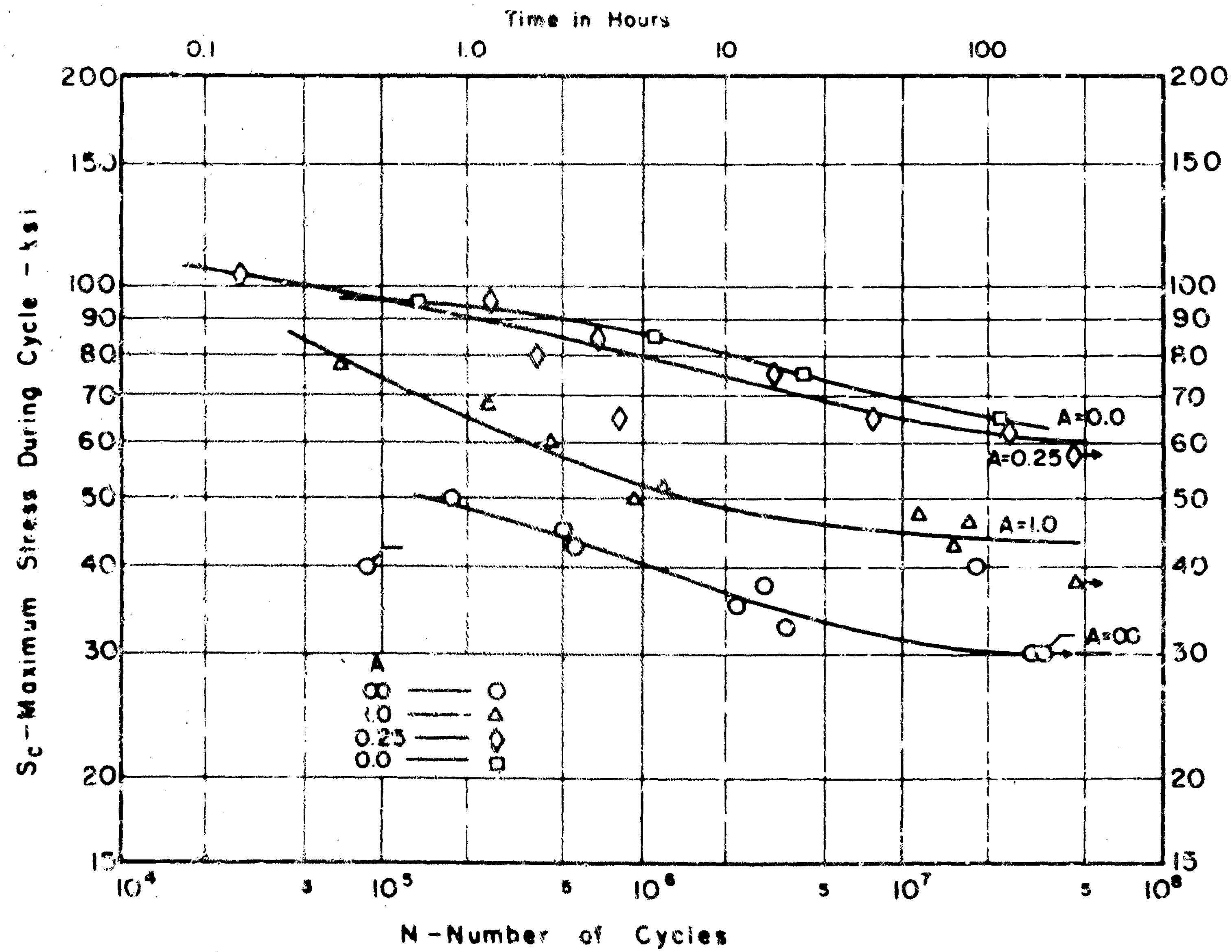


Figure 14 S-N Fatigue Diagram for Unnotched Specimens of the Alloy Nicrotung at Various Alternating-to-Mean Stress Ratios and at 1500°F.

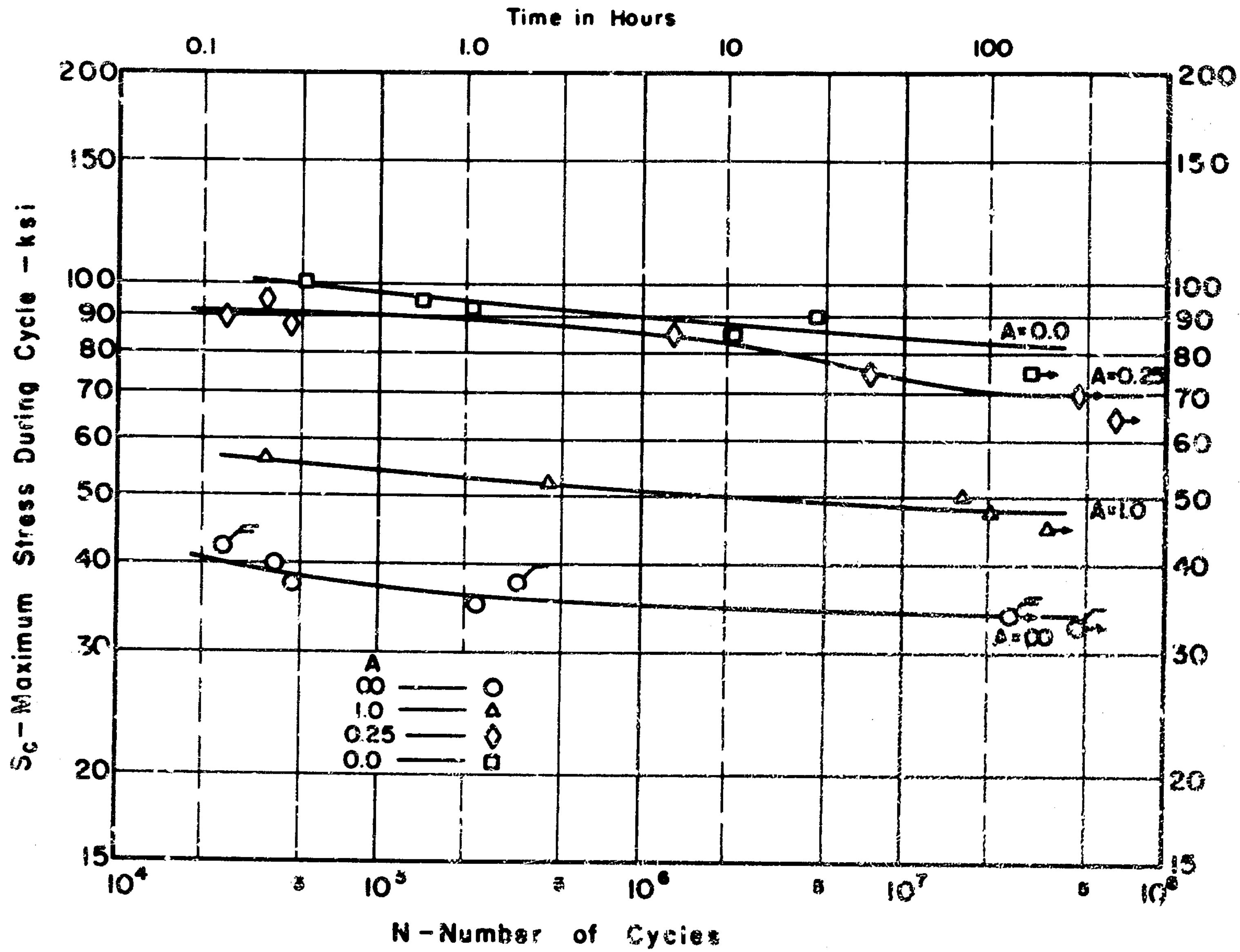


Figure 15 S-N Fatigue Diagram for Notched (K_t = 2.0) Specimens of the Alloy Nicrotung at Various Alternating-to-Mean Stress Ratios and at 1500°F.

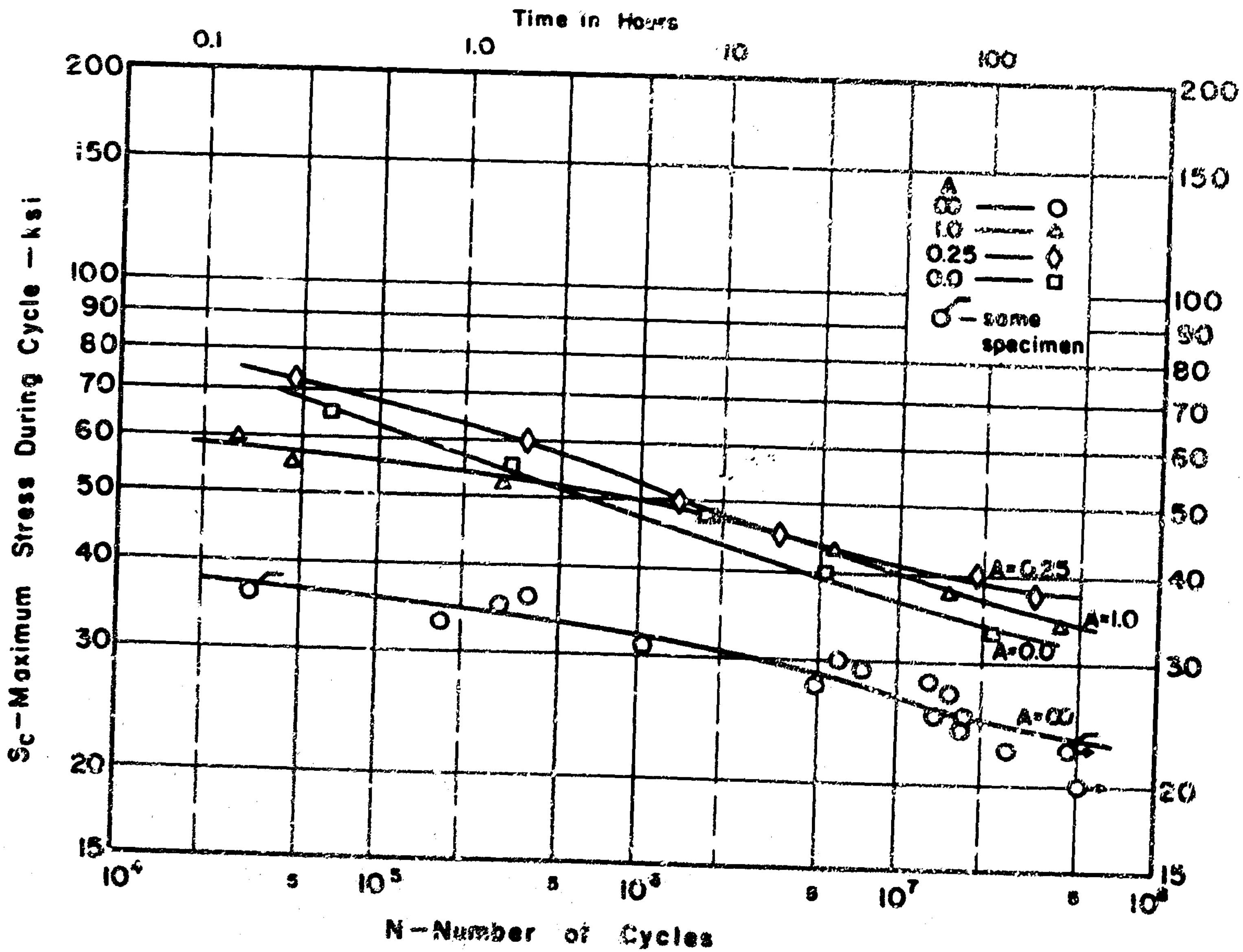


Figure 16 S-N Diagram for Unnotched Specimens of the Alloy Nicrotung at Various Alternating-to-Mean Stress Ratios and at 1700°F.

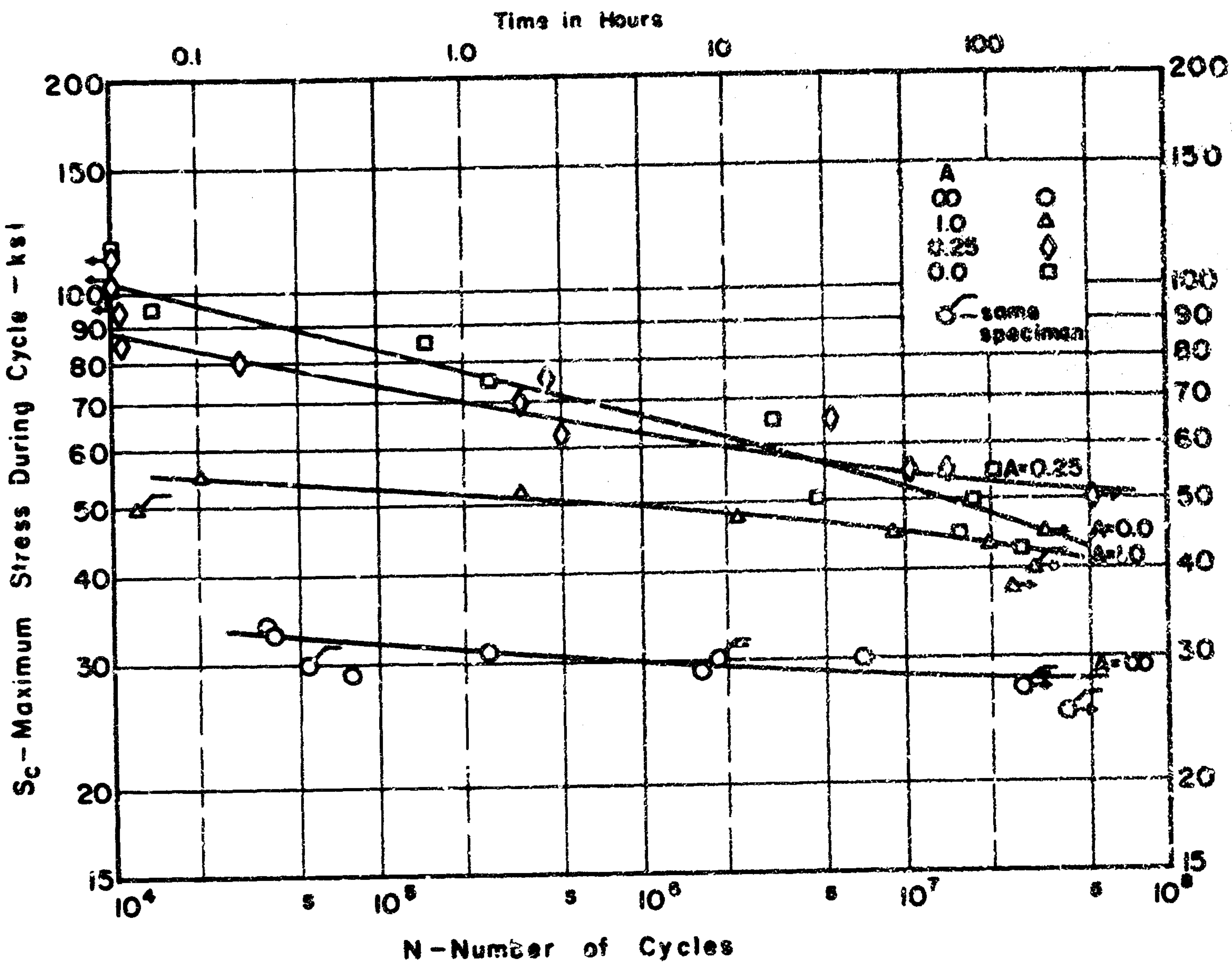


Figure 17 S-N Fatigue Diagram for Notched (K_t = 2.0) Specimens of the Alloy Nicrotung at Various Alternating-to-Mean Stress Ratios and at 1700°F.

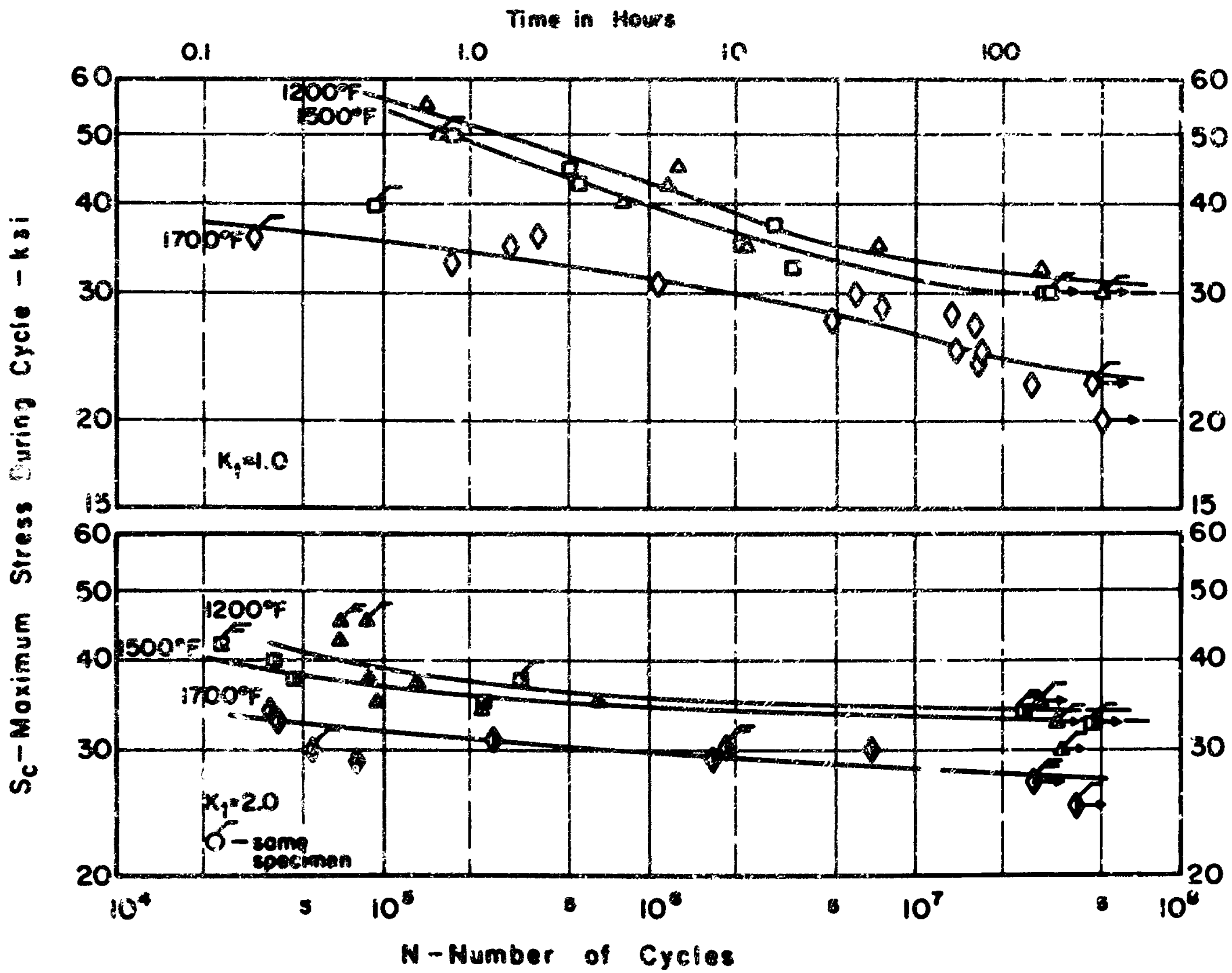


Figure 18 S-N Fatigue Diagram for Unnotched (a) and Notched (b, K_t = 2.0) Specimens of the Alloy Nicrotung Under Reversed Stress (A = ∞) and at 1200°F, 1500°F, and 1700°F.

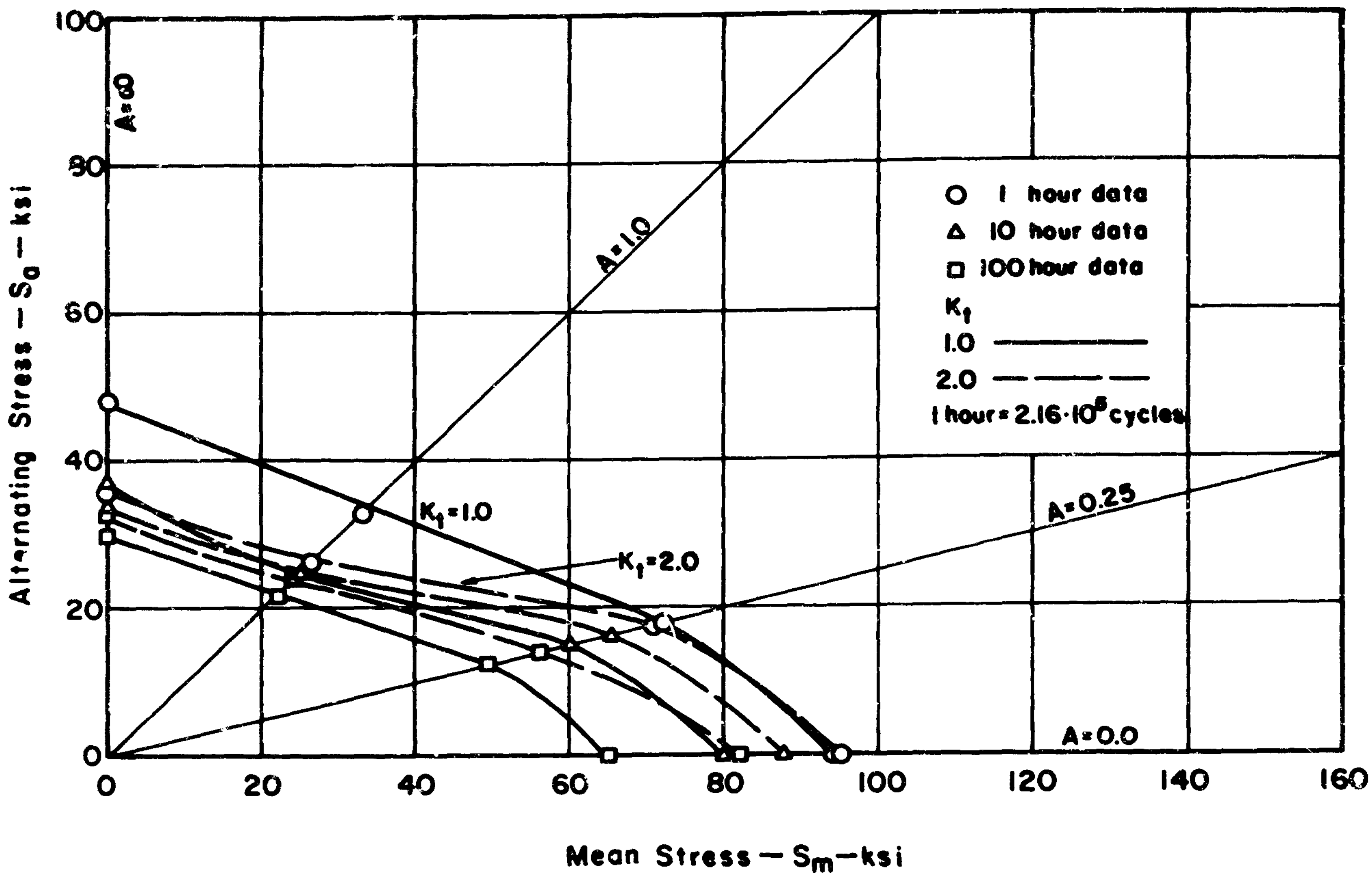


Figure 19 Stress Range Diagram for Unnotched and Notched Specimens of the Alloy Nicrotung at 1500°F.

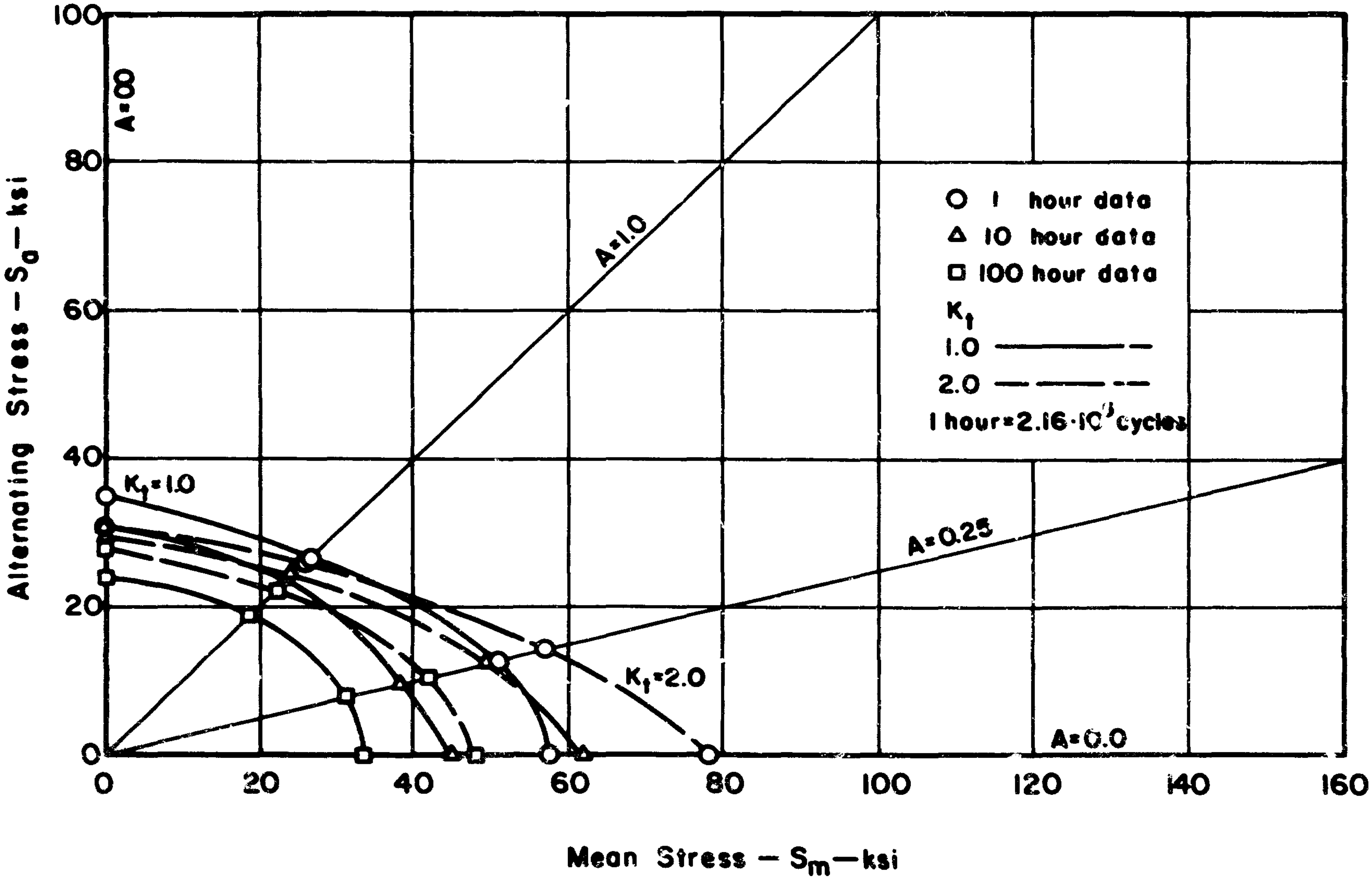


Figure 20 Stress Range Diagram for Unnotched and Notched Specimens of the Alloy Nicrotung at 1700°F.

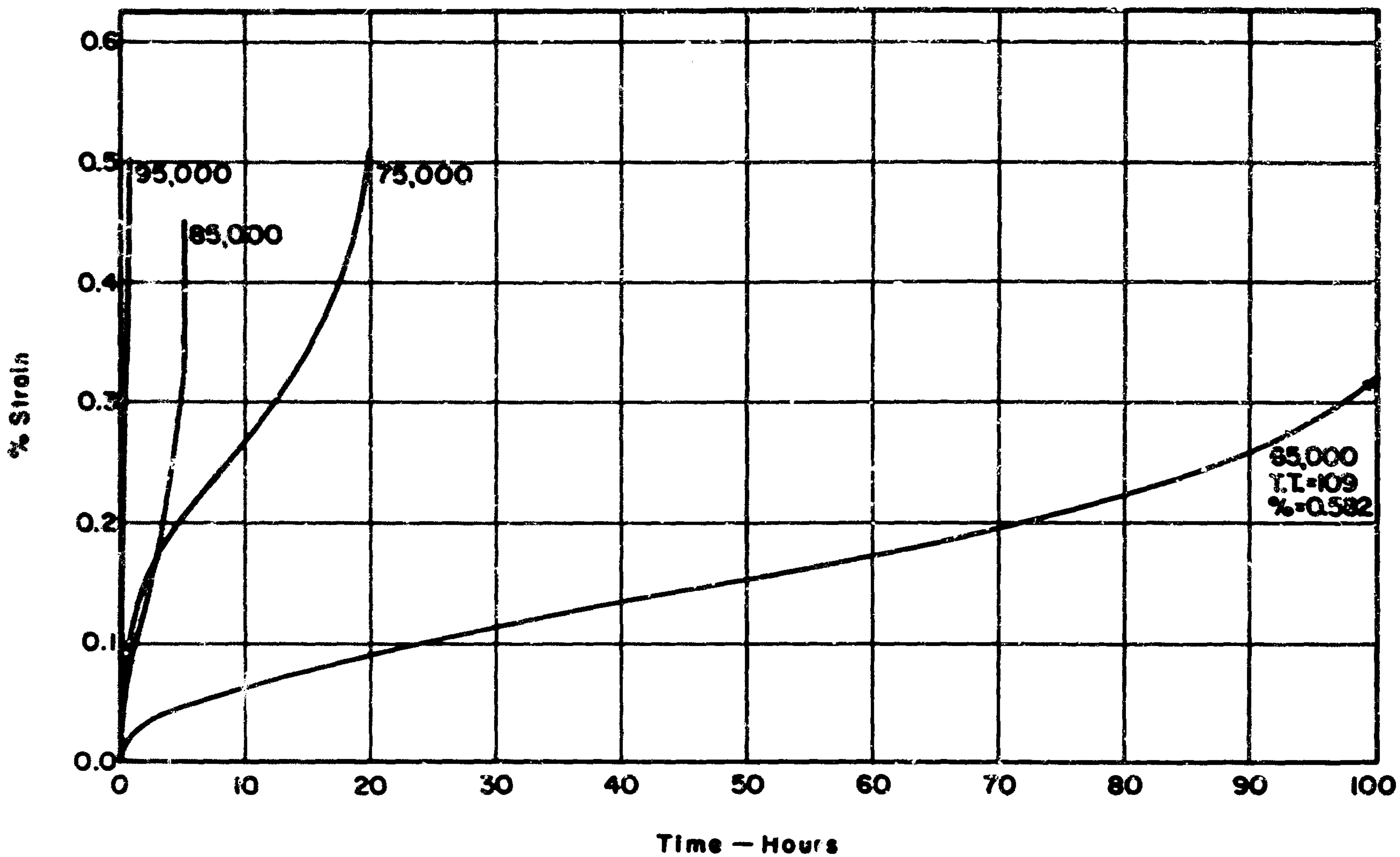


Figure 21 Creep Time Curves for the Alloy Nicrotung Under Static Load (A = 0) at 1500°F.

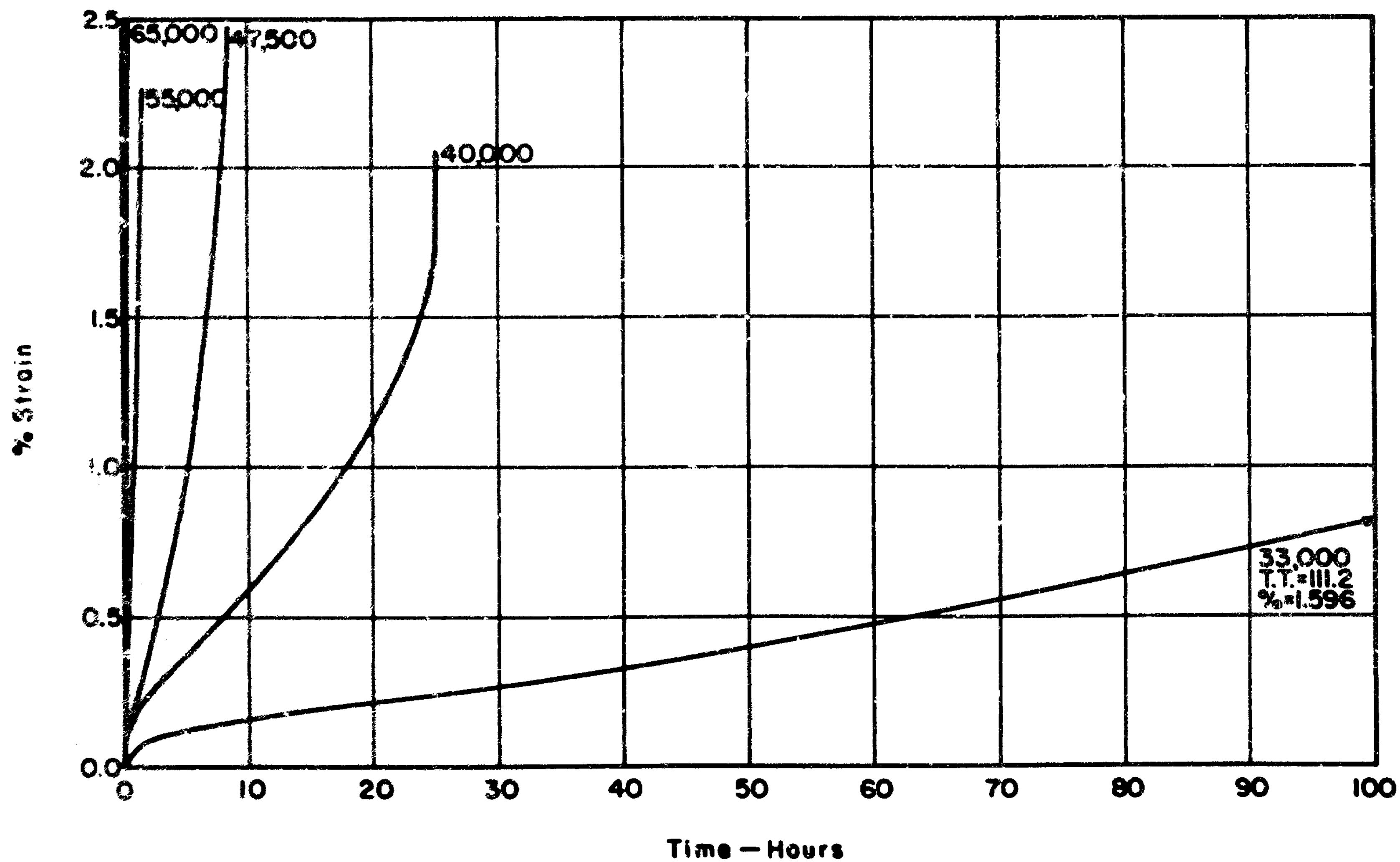


Figure 22 Creep Time Curves for the Alloy Nicrotung Under Static Load (A = 0) at 1700°F.

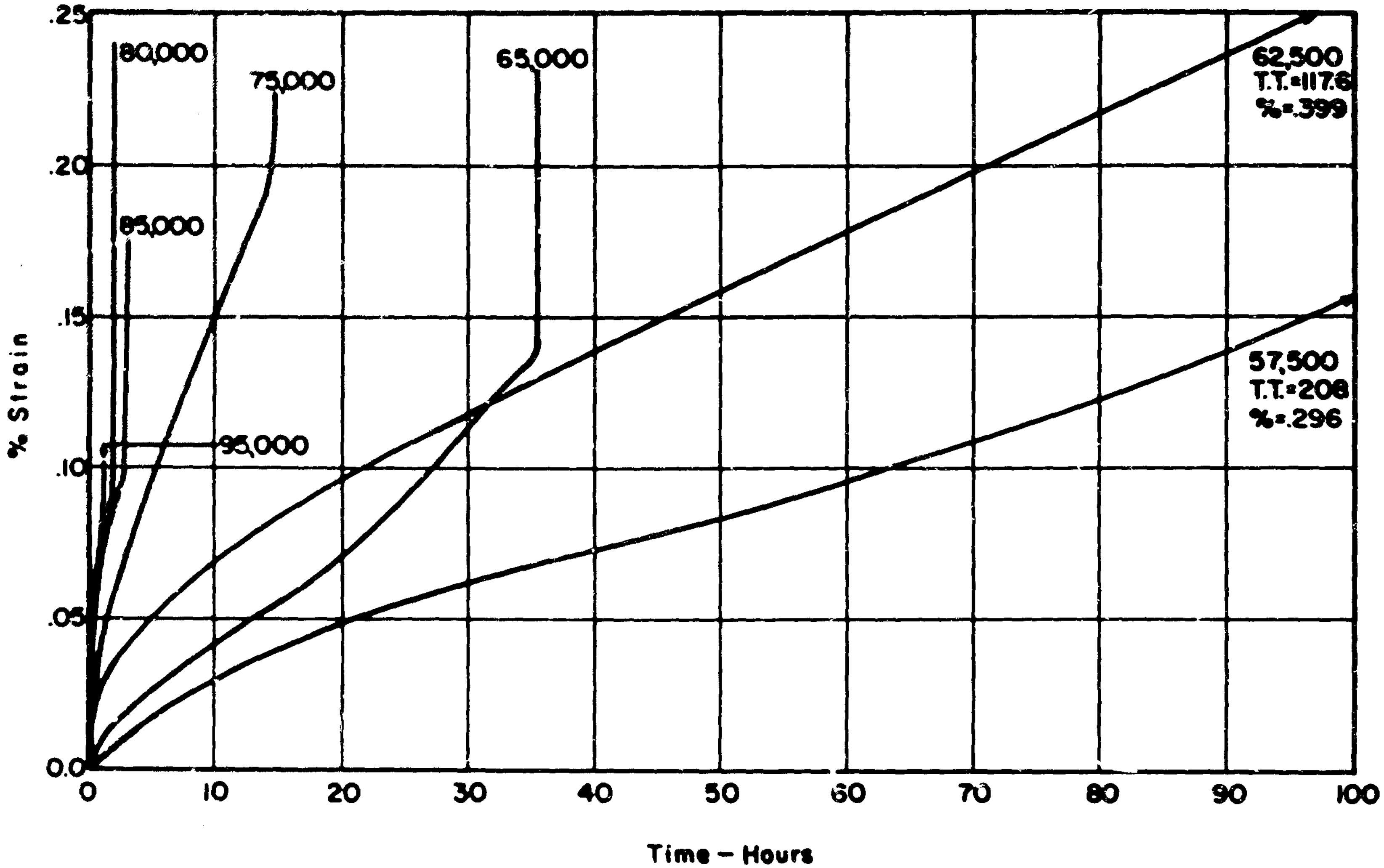


Figure 23 Creep Time Curves for the Alloy Nicrotung at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1500°F.

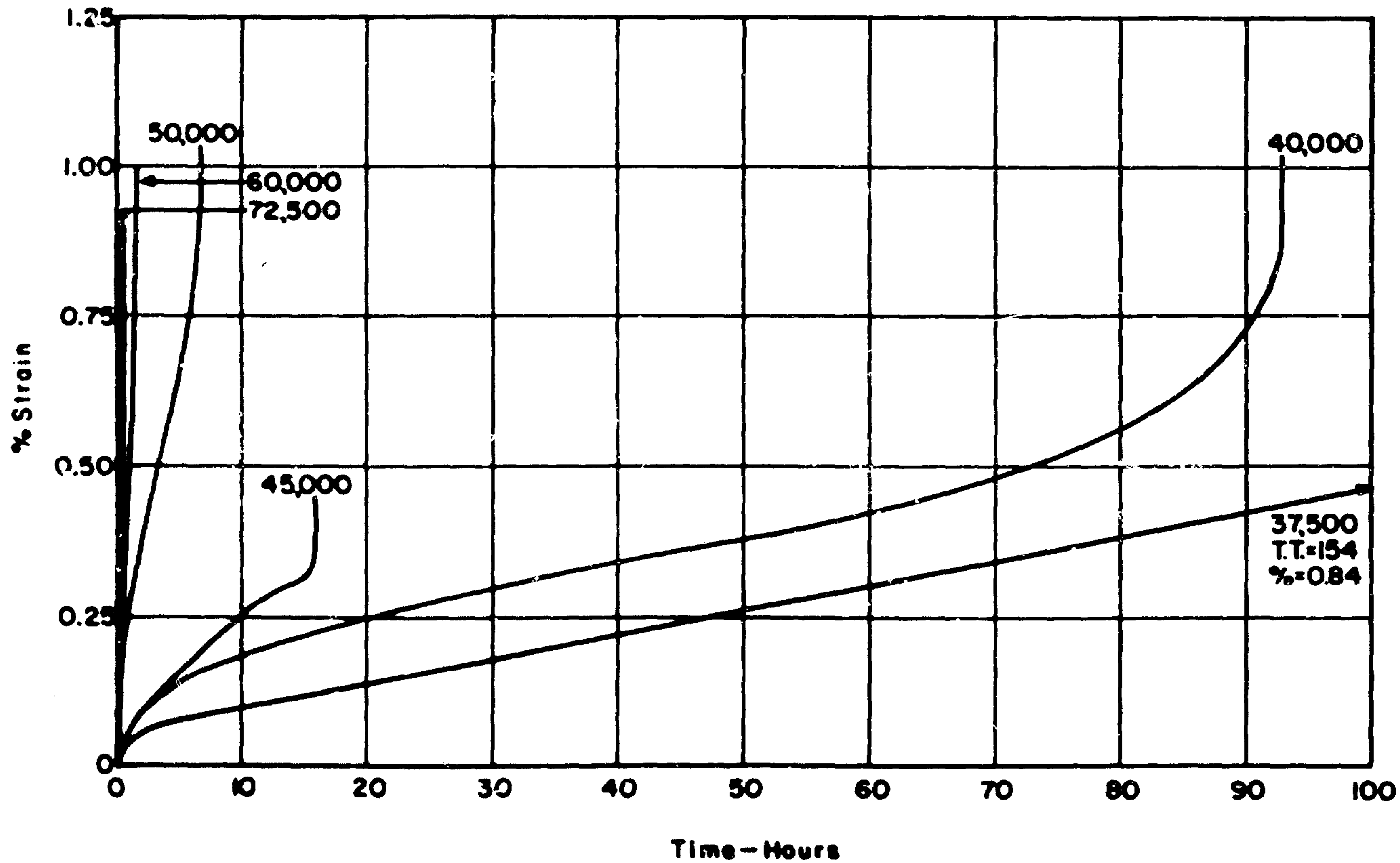


Figure 24 Creep Time Curves for the Alloy Nicrotung at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1700°F.

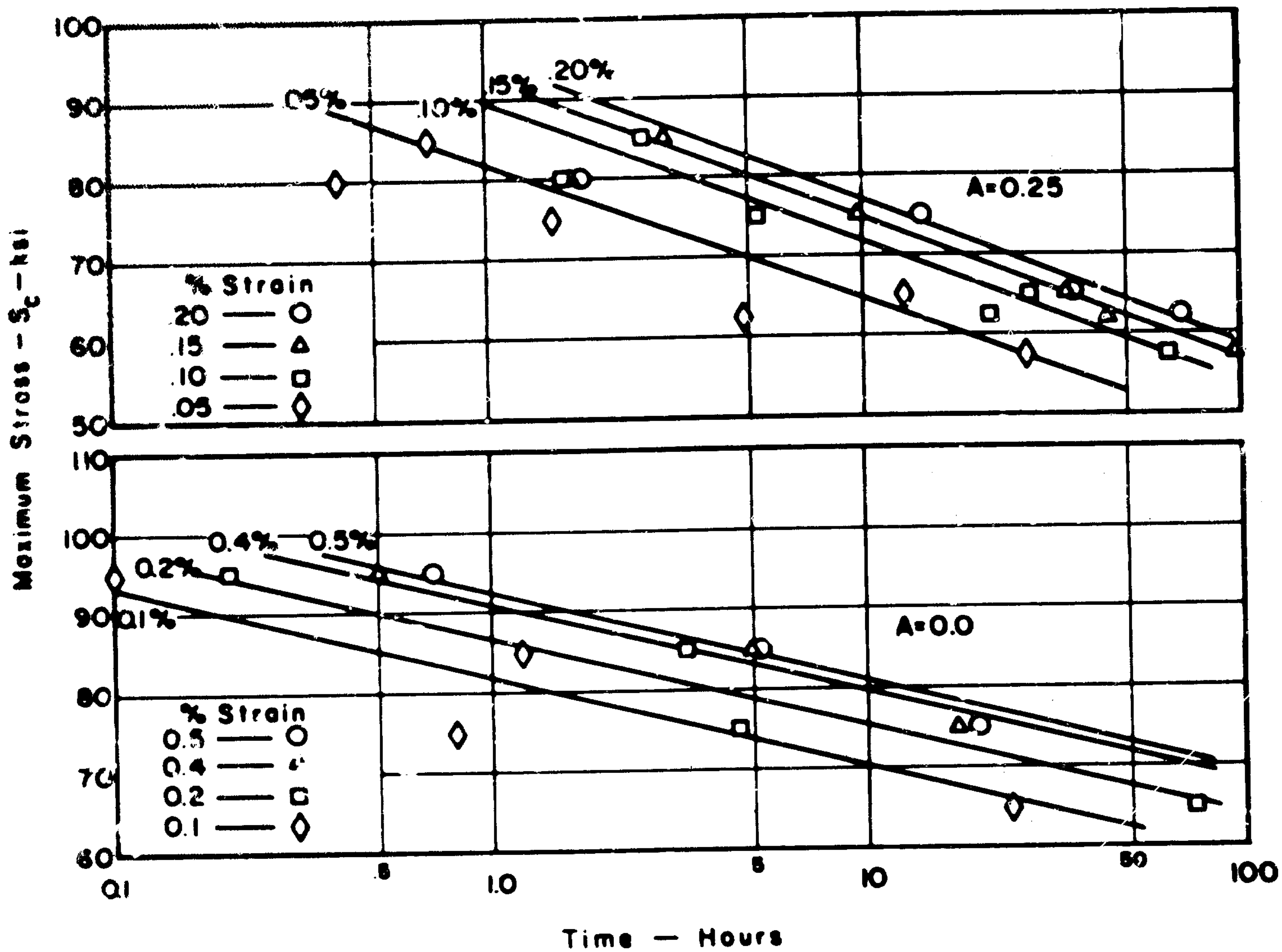


Figure 25 Maximum Stress Versus Time for Various Amounts of Creep for the Alloy Nicrotung at Alternating-to-Mean Stress Ratios A = 0 and 0.25 and at 1500°F.

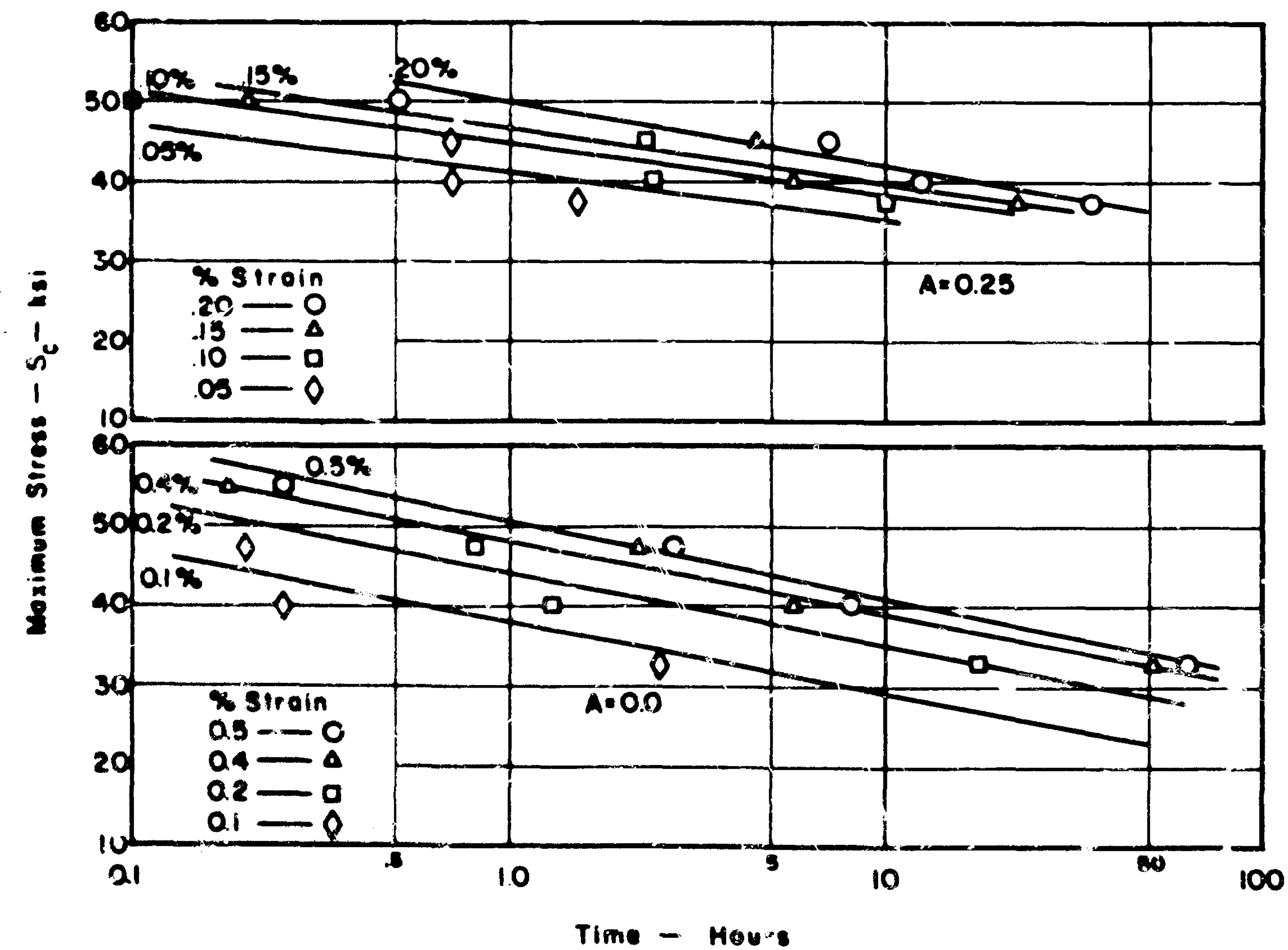


Figure 26 Maximum Stress Versus Time for Various Amounts of Creep for the Alloy Nicrotung at Alternating-to-Mean Stress Ratios A = 0 and 0.25 and at 1700°F.

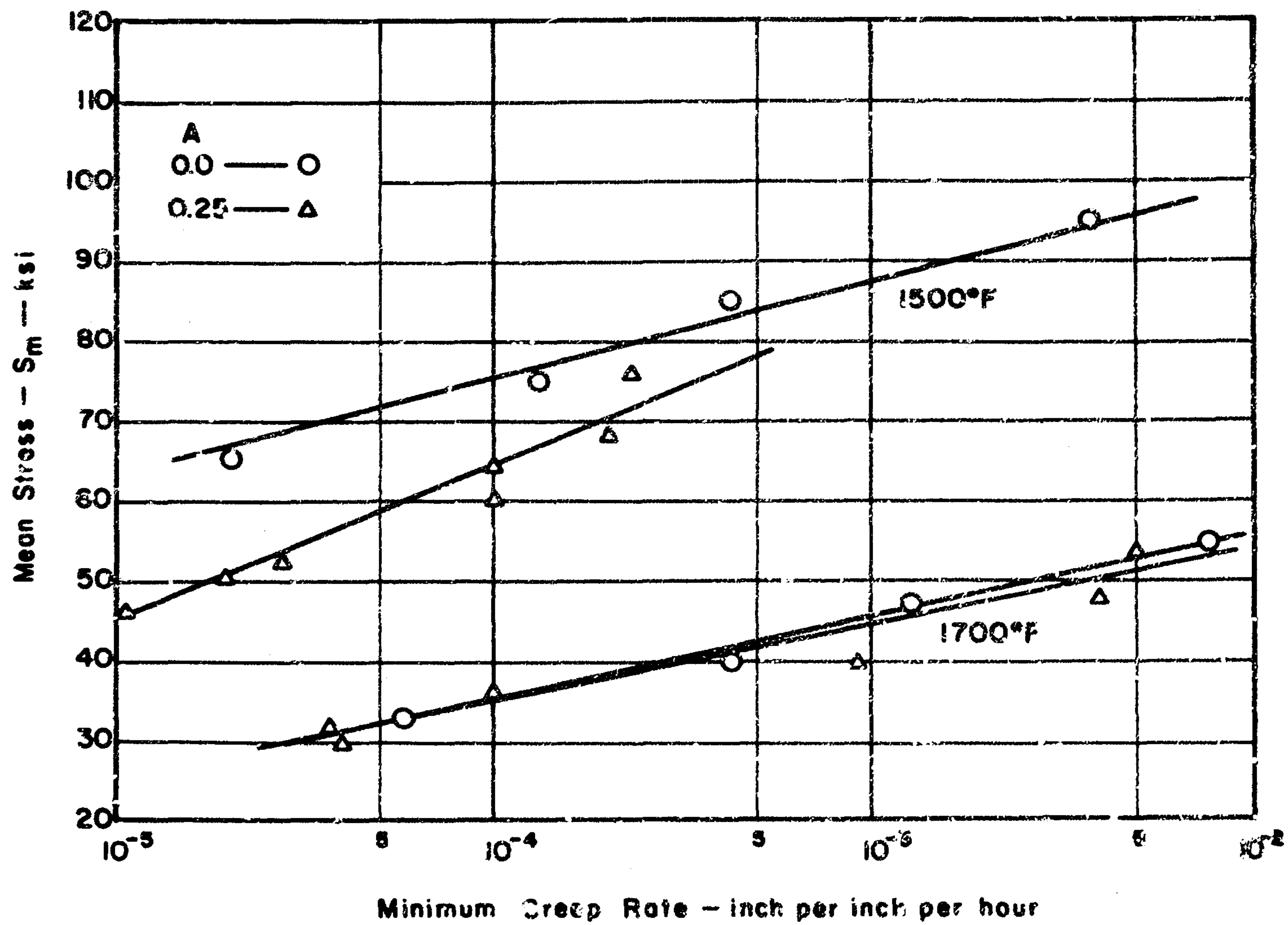


Figure 27 Minimum Creep Rate Versus Mean Stress for the Alloy Nicrotung at Various Alternating-to-Mean Stress Ratios and at 1500°F and 1700°F.

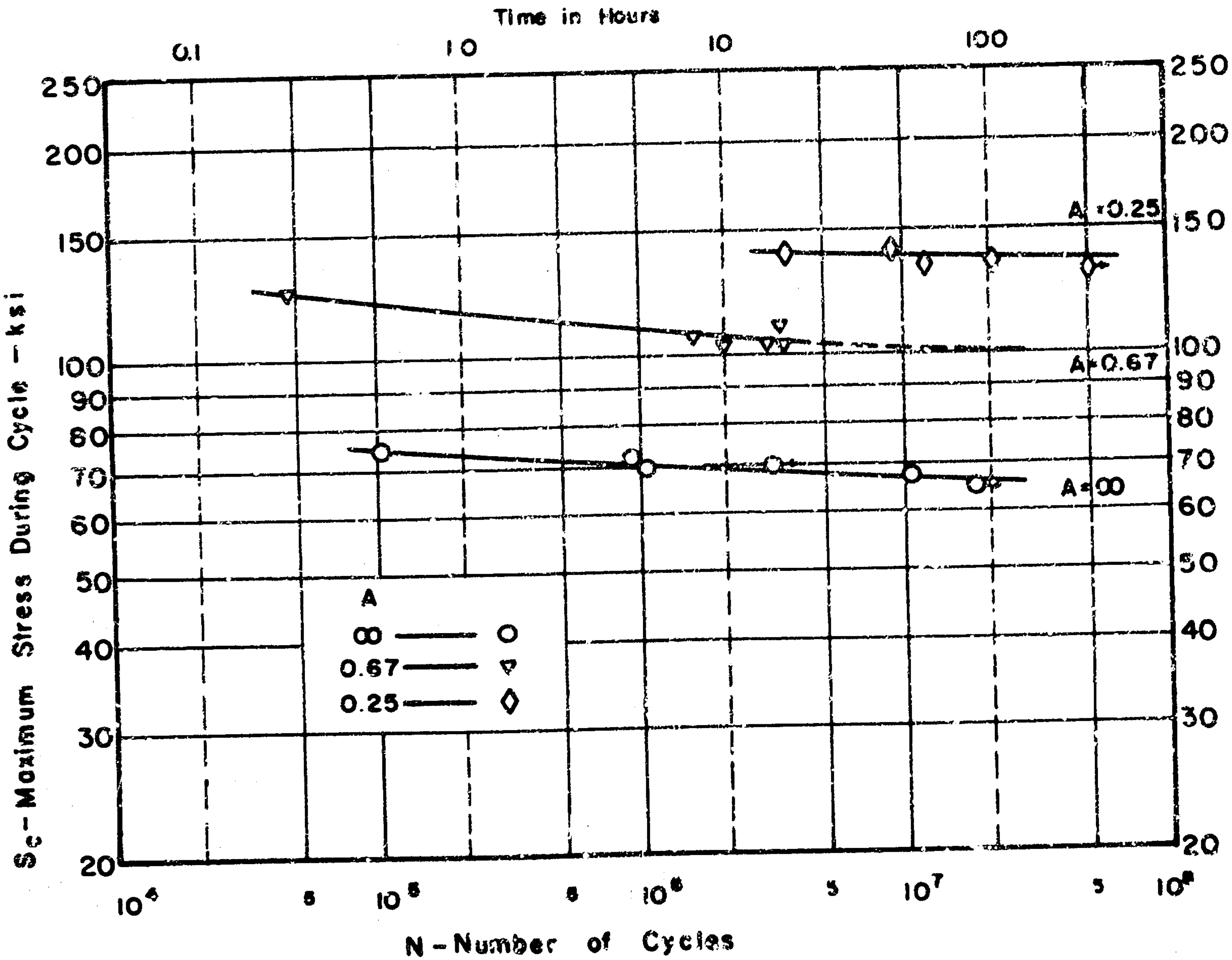


Figure 28 S-N Fatigue Diagram for Unnotched Specimens of Super A-286 at Various Alternating-to-Mean Stress Ratios and at 800°F.

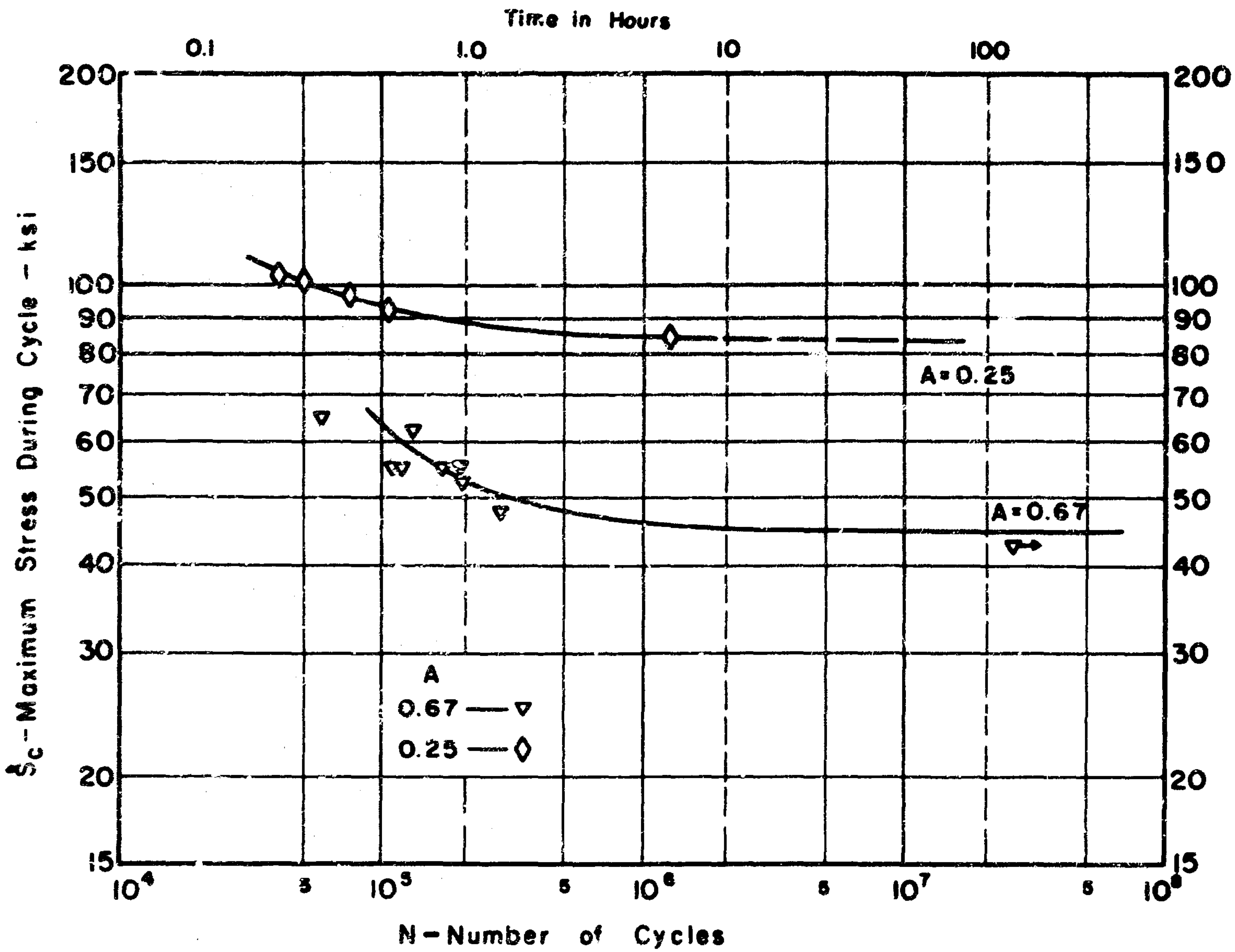


Figure 29 S-N Fatigue Diagram for Notched (K_t = 3.4) Specimens of Super A-286 at Various Alternating-to-Mean Stress Ratios and at 800°F.

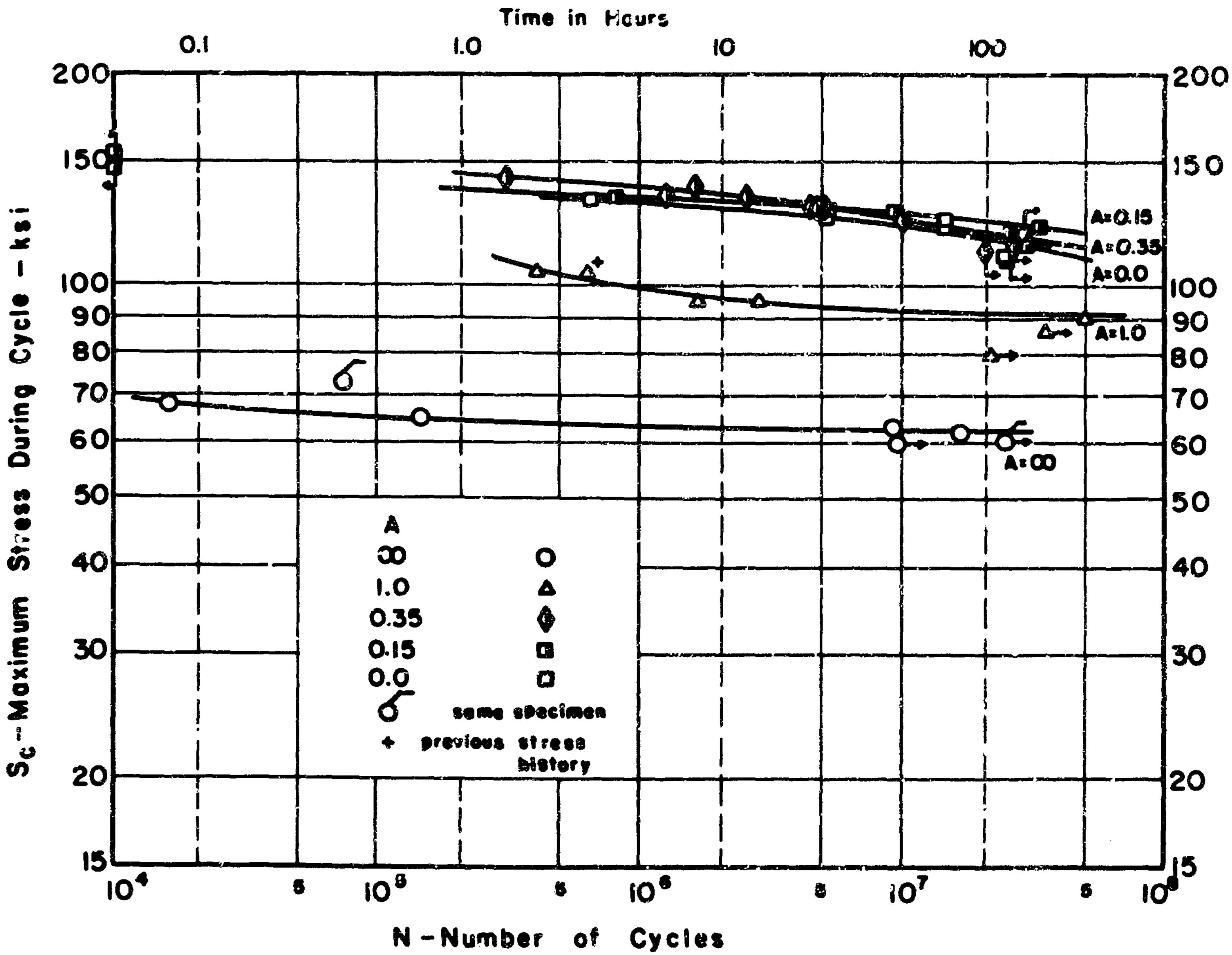


Figure 30 S-N Fatigue Diagram for Unnotched Specimens of Super A-286 at Various Alternating-to-Mean Stress Ratios and at 1000°F.

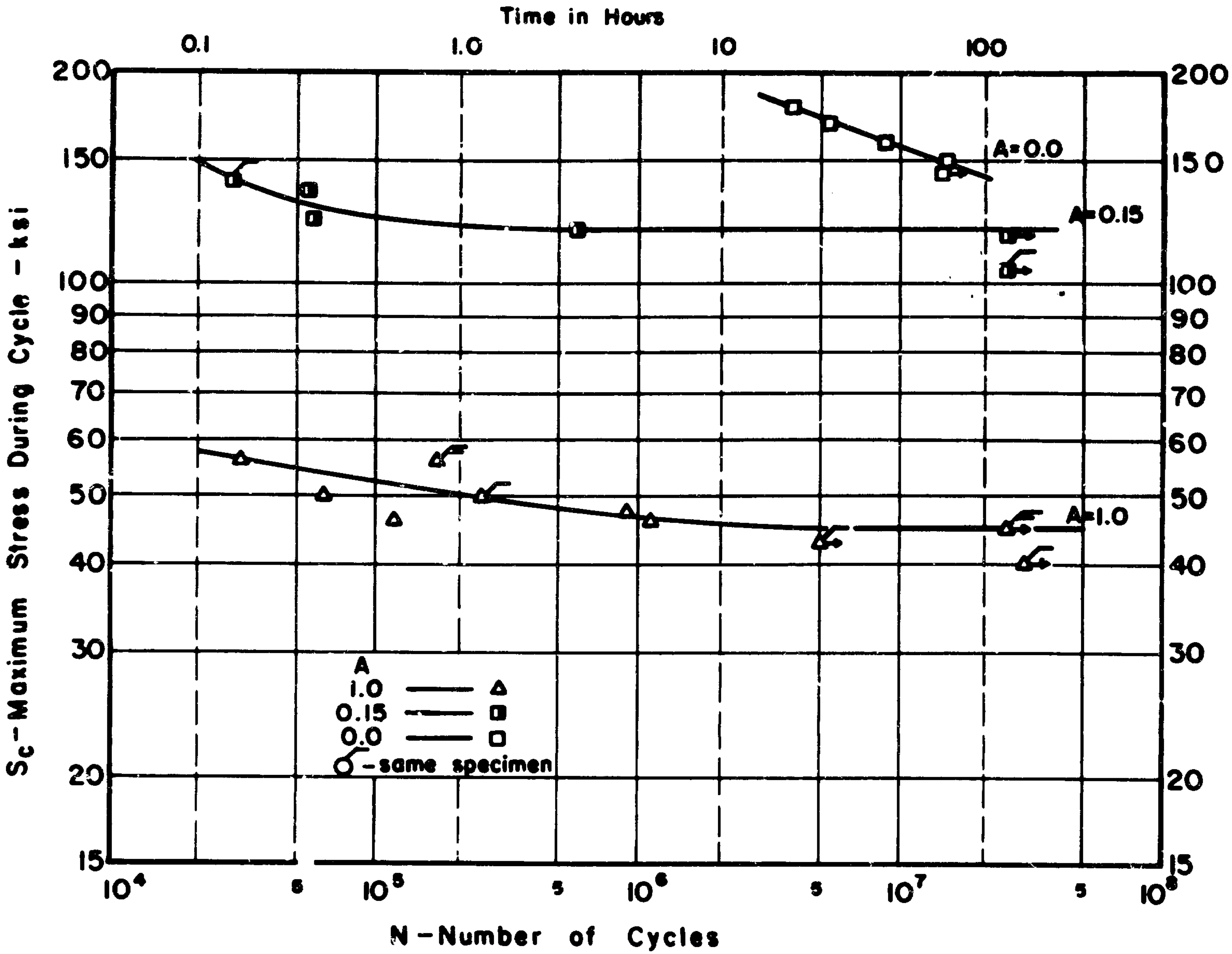


Figure 31 S-N Fatigue Diagram for Notched (K_t = 3.4) Specimens of Super A-286 at Various Alternating-to-Mean Stress Ratios and at 1000°F.

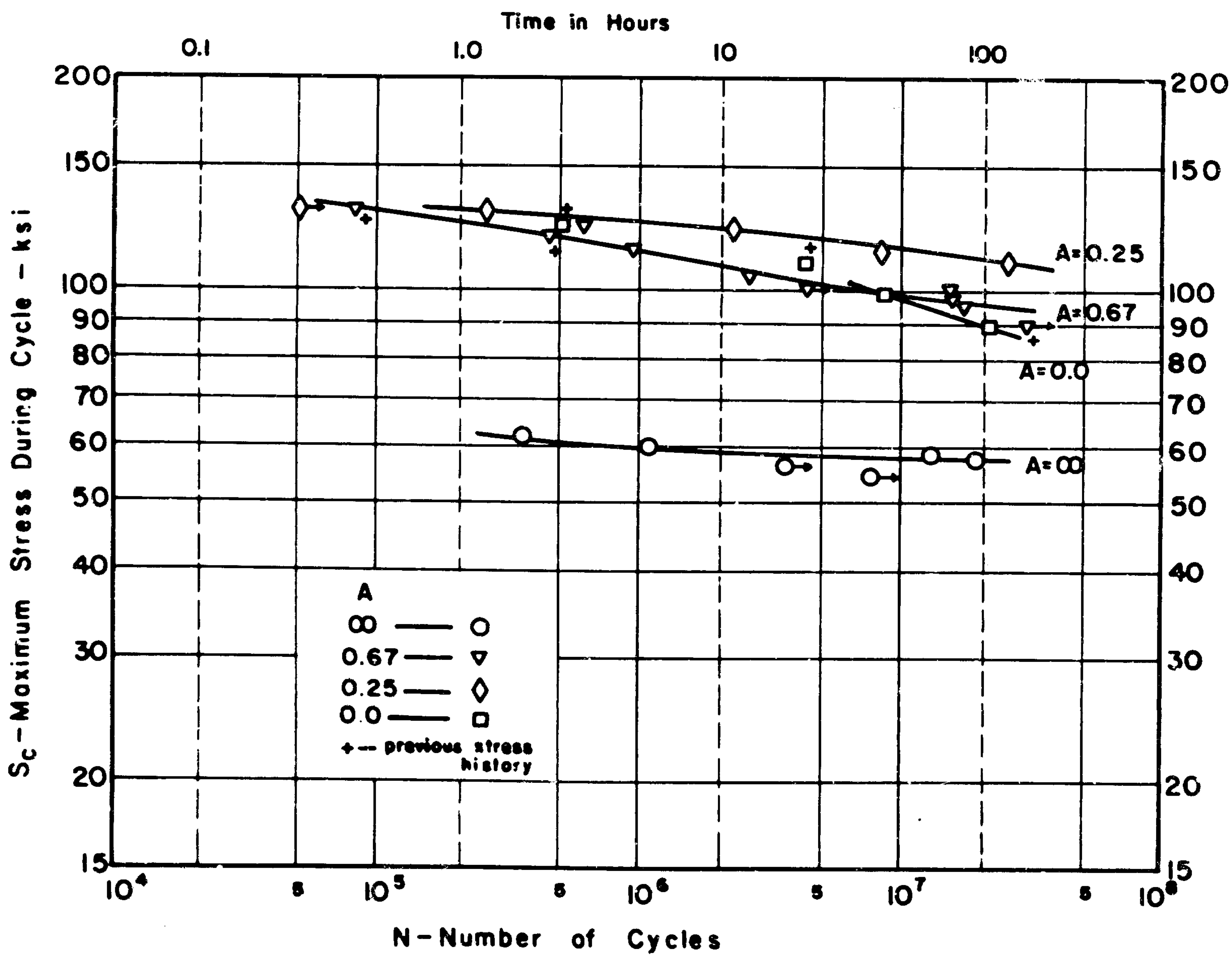


Figure 32 S-N Fatigue Diagram for Unnotched Specimens of Super A-286 at Various Alternating-to-Mean Stress Ratios and at 1100°F.

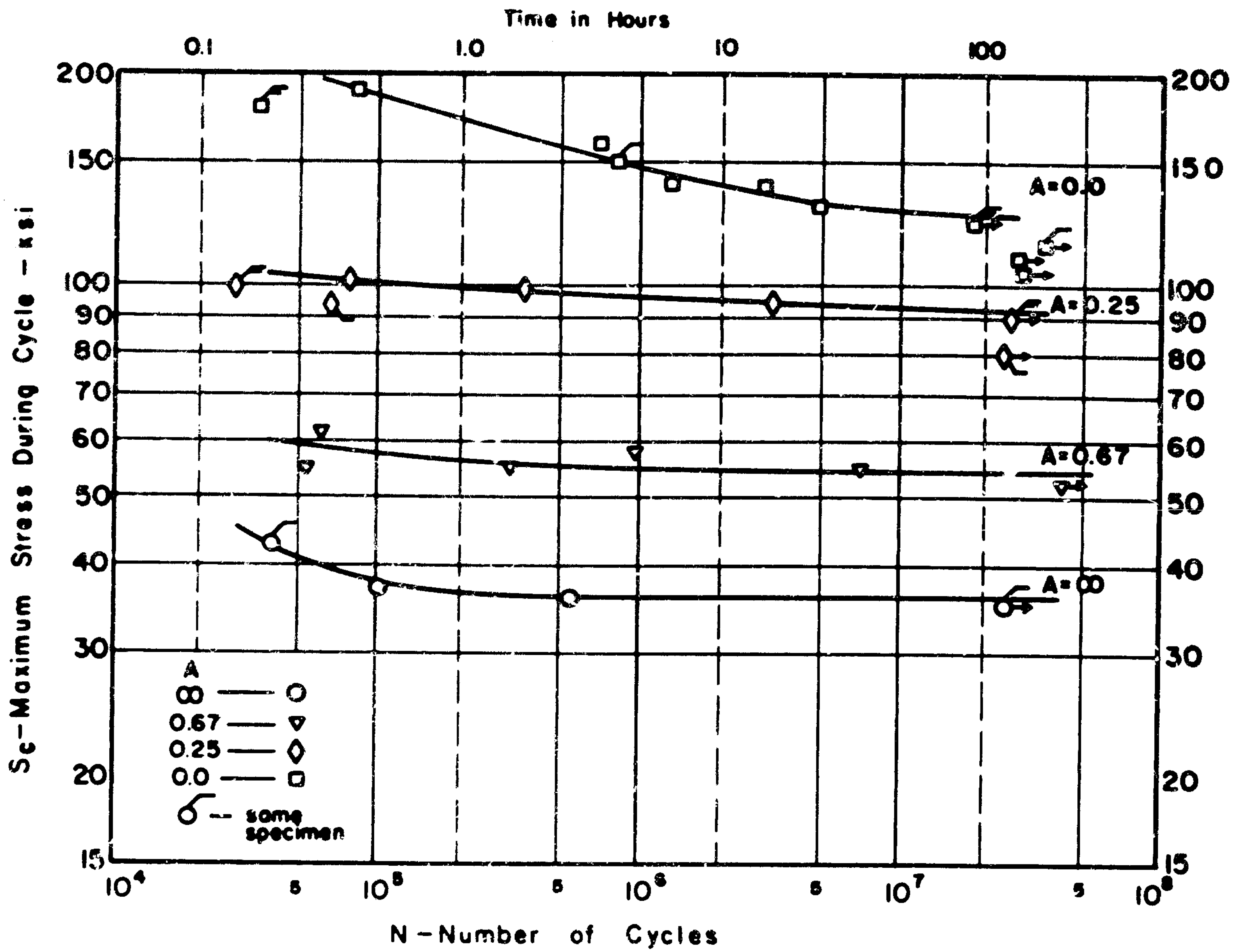


Figure 33 S-N Fatigue Diagram for Notched ($K_t = 3.4$) Specimens of Super A-286 at Various Alternating-to-Mean Stress Ratios and at 1100°F.

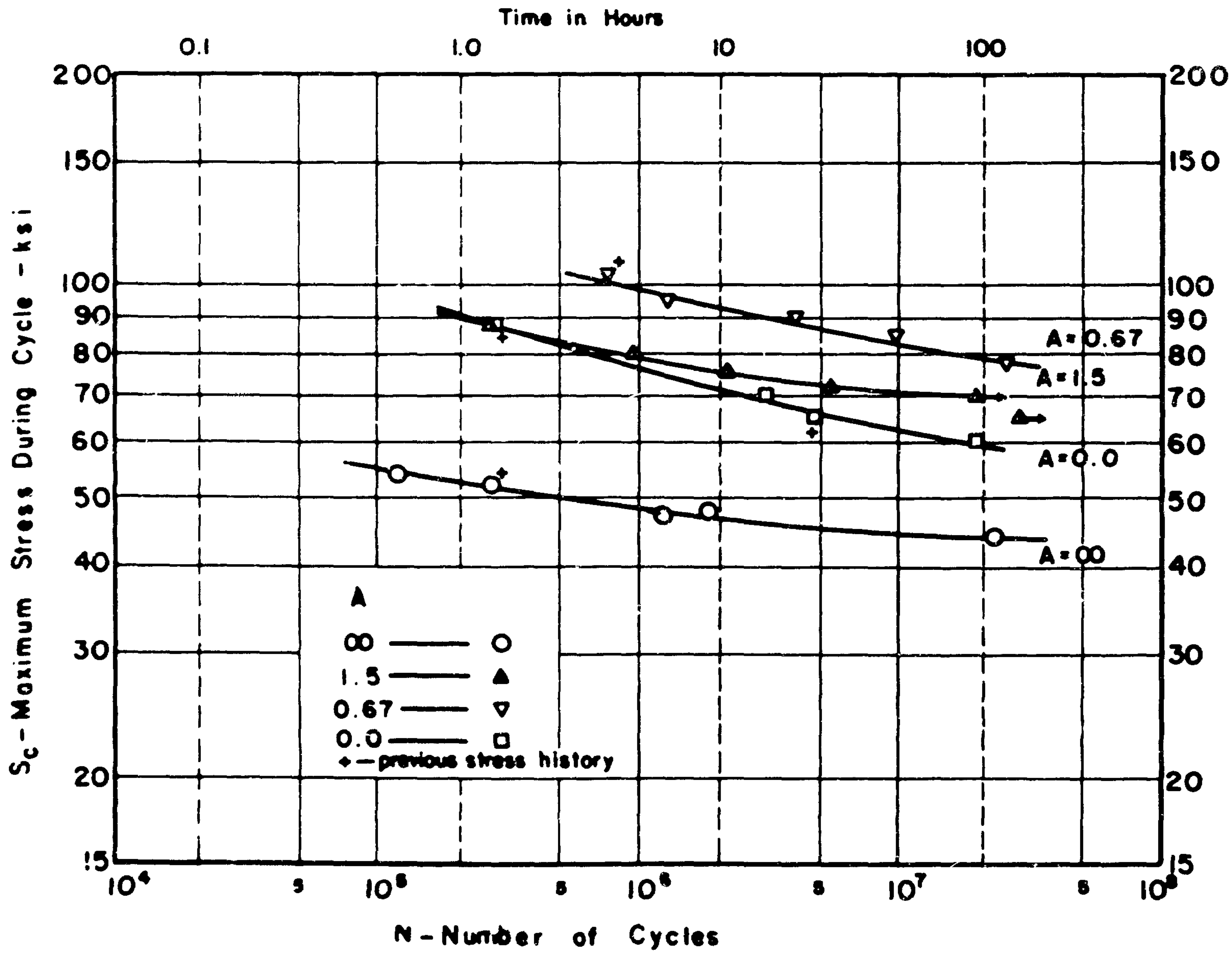


Figure 34 S-N Fatigue Diagram for Unnotched Specimens of Super A-286 at Various Alternating-to-Mean Stress Ratios and at 1250°F.

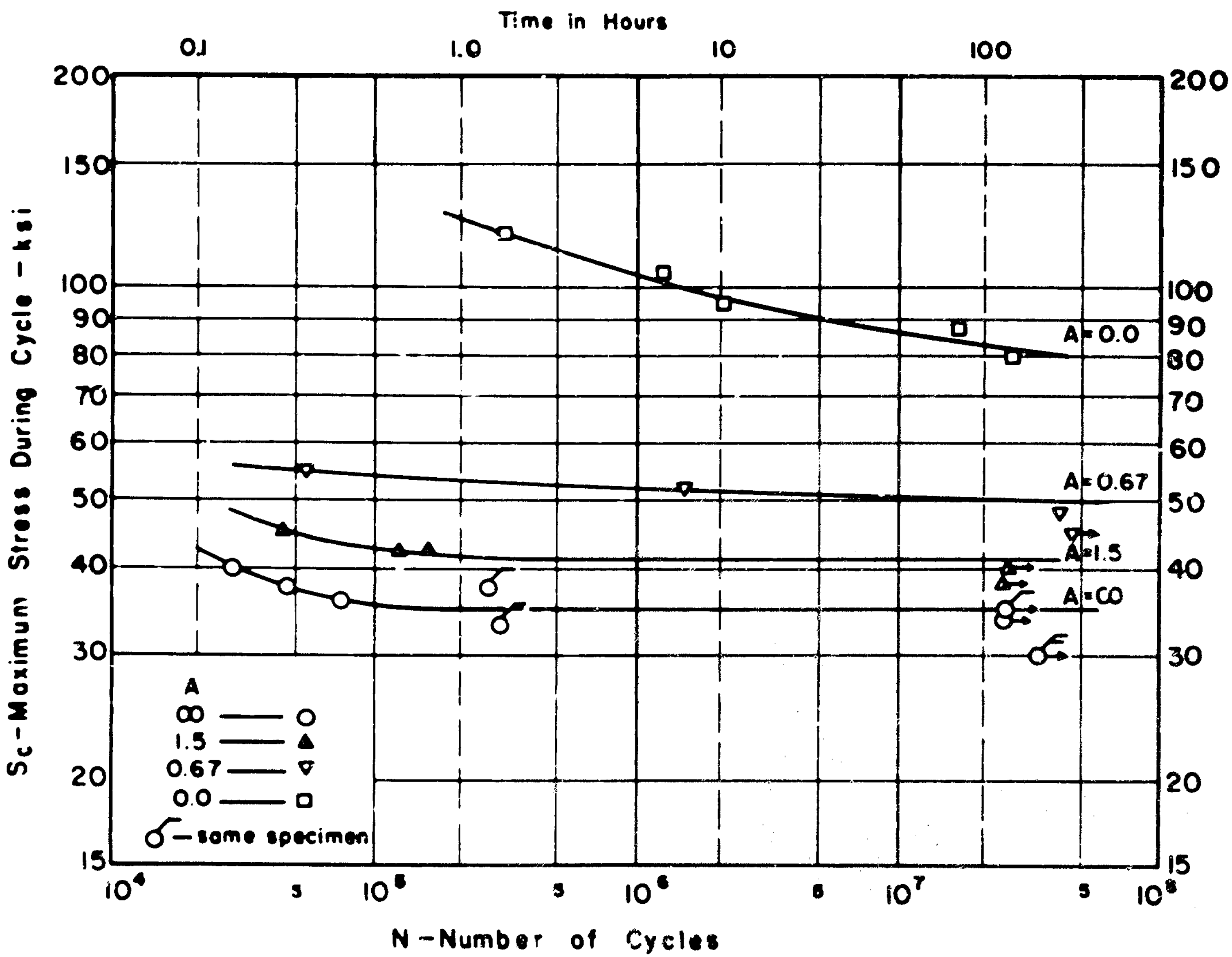


Figure 35 S-N Fatigue Diagram for Notched (K_t = 3.4) Specimens of Super A-286 at Various Alternating-to-Mean Stress Ratios and at 1250°F.

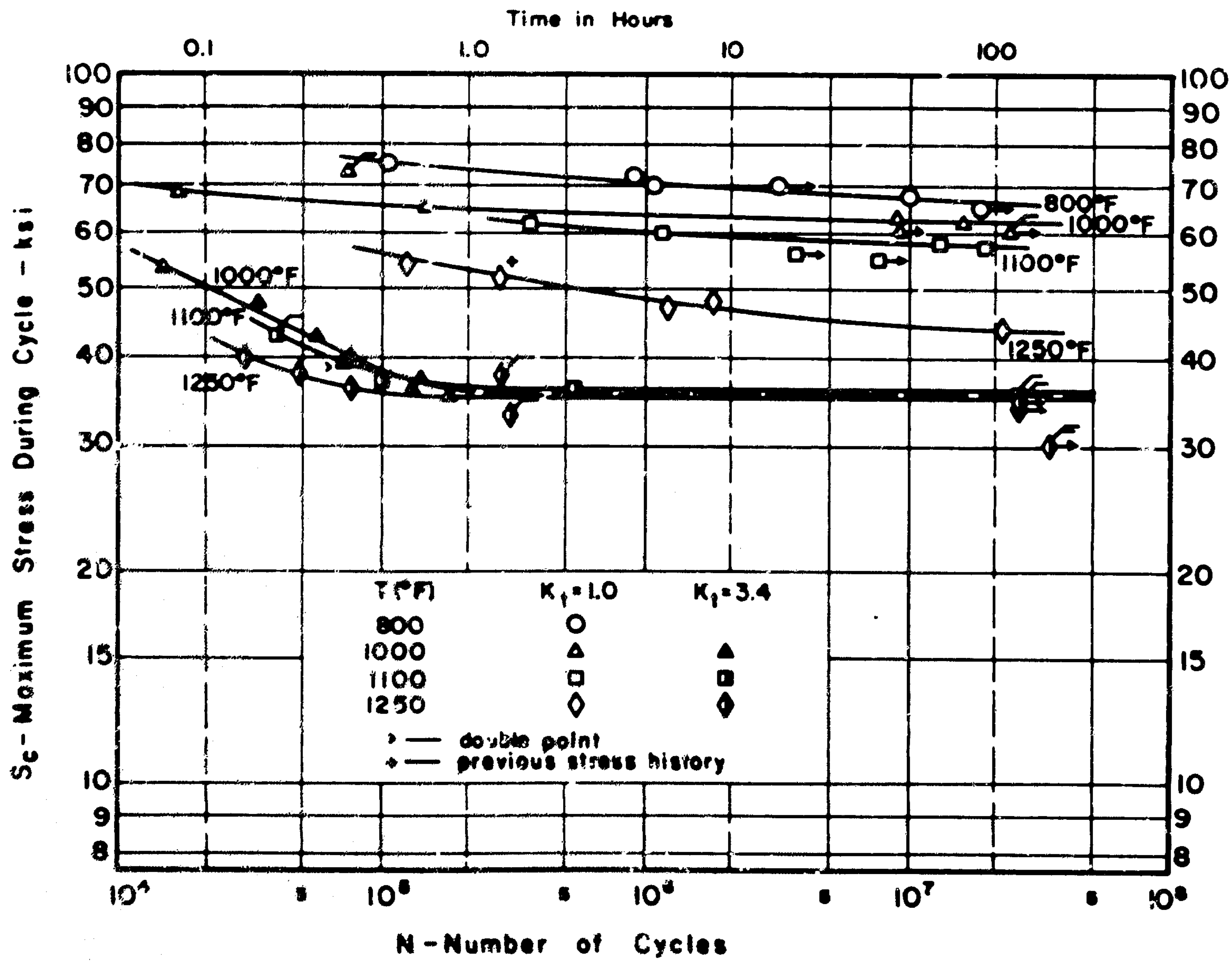


Figure 36 S-N Fatigue Diagram for Unnotched and Notched (K_t = 3.4) Specimens of Super A-286 Under Reversed Stress (A = ∞) and at 800°F, 1000°F, 1100°F, and 1250°F.

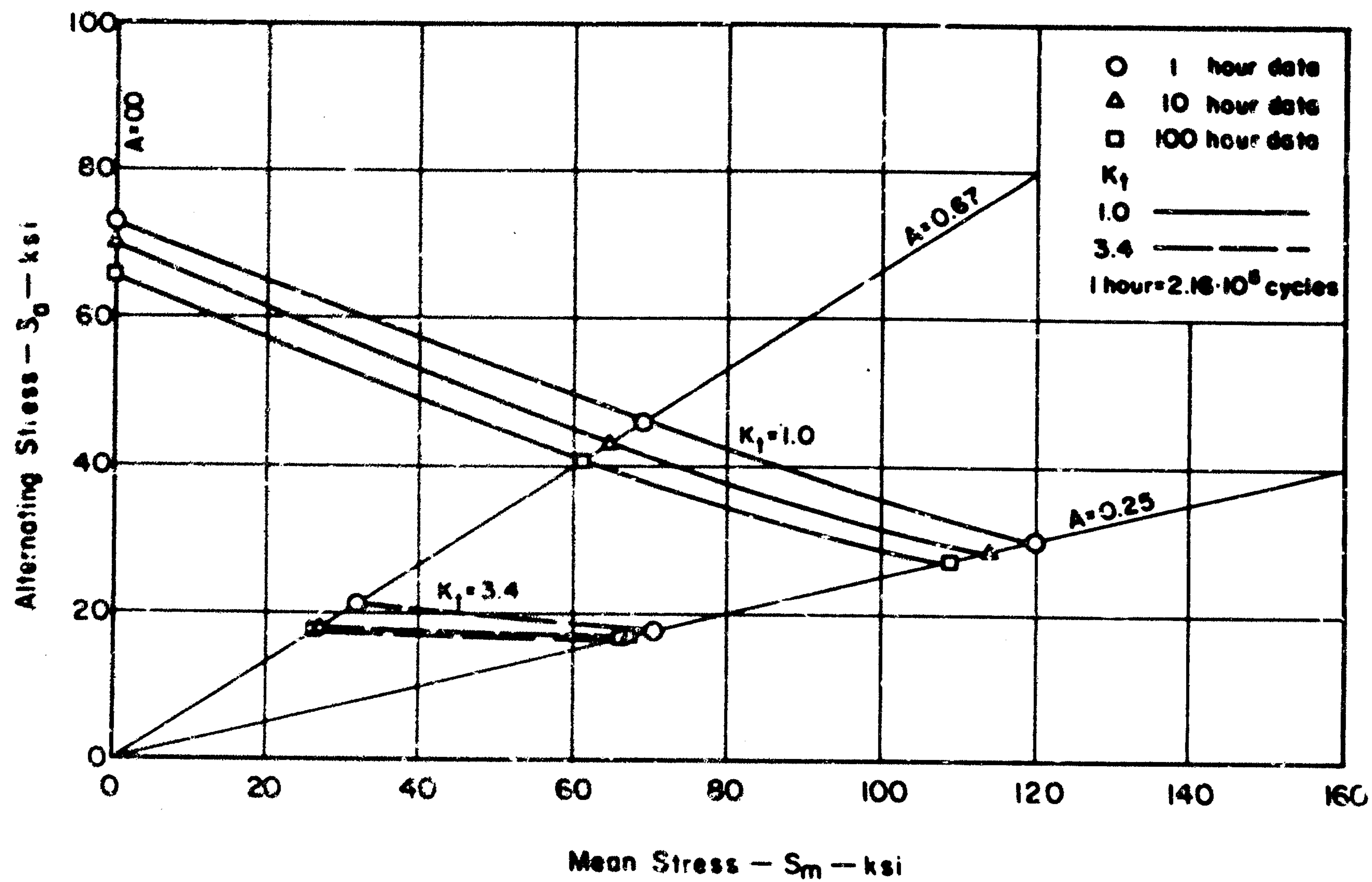


Figure 37 Stress Range Diagram for Unnotched and Notched Specimens of Super A-286 at 800°F.

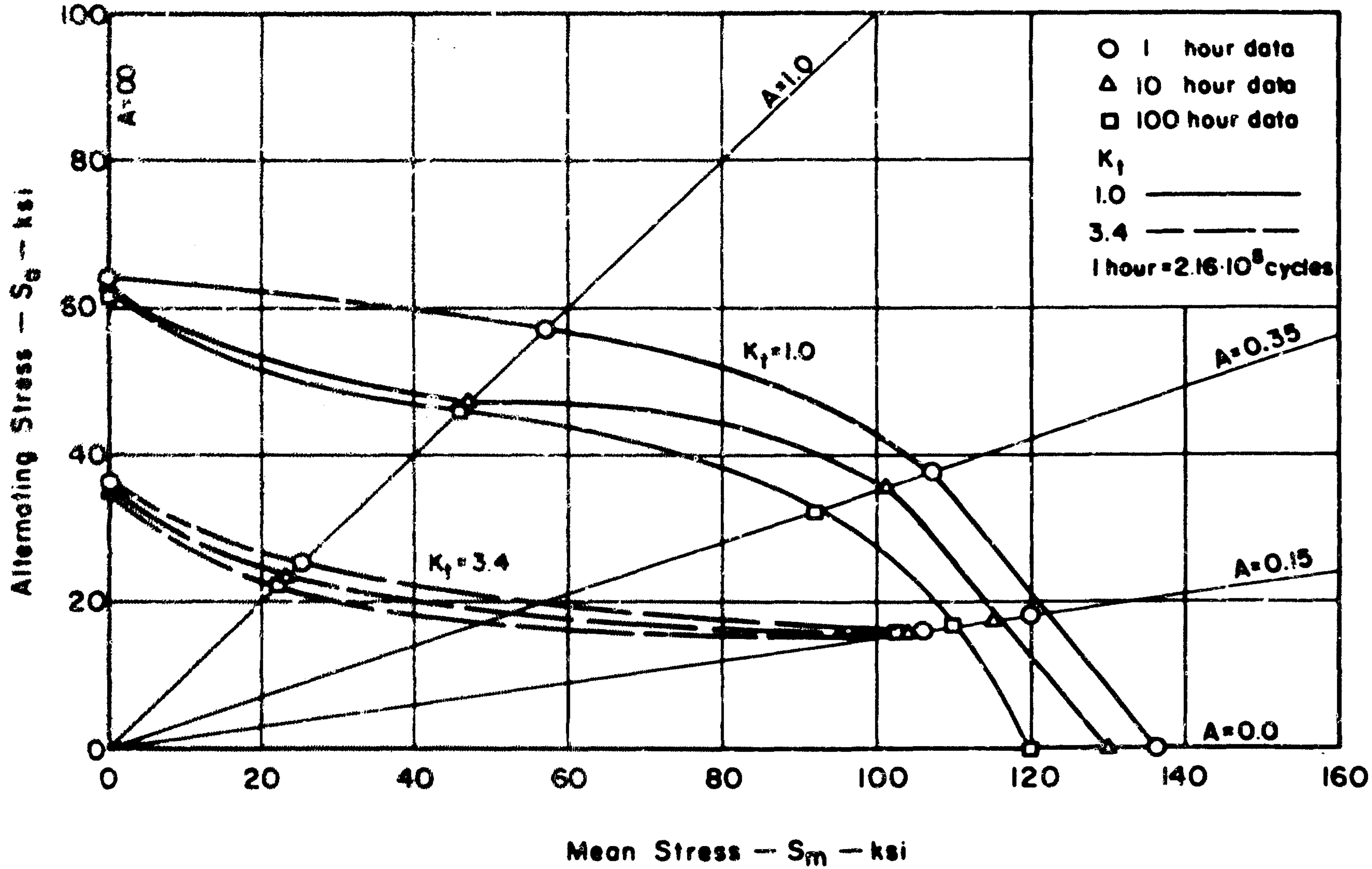


Figure 38 Stress Range Diagram for Unnotched and Notched Specimens of Super A-286 at 1000°F.

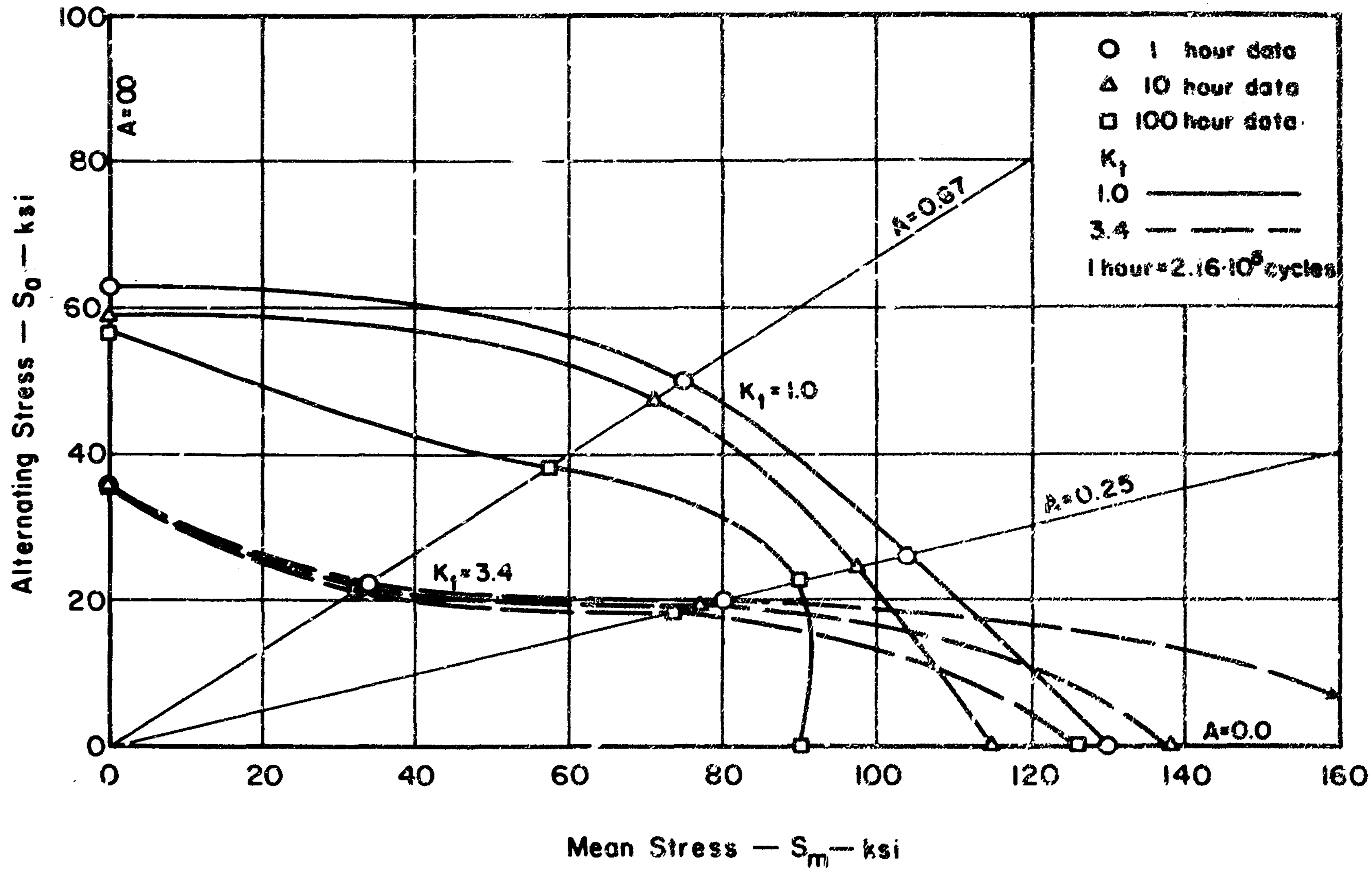


Figure 39 Stress Range Diagram for Unnotched and Notched Specimens of Super A-286 at 1100°F.

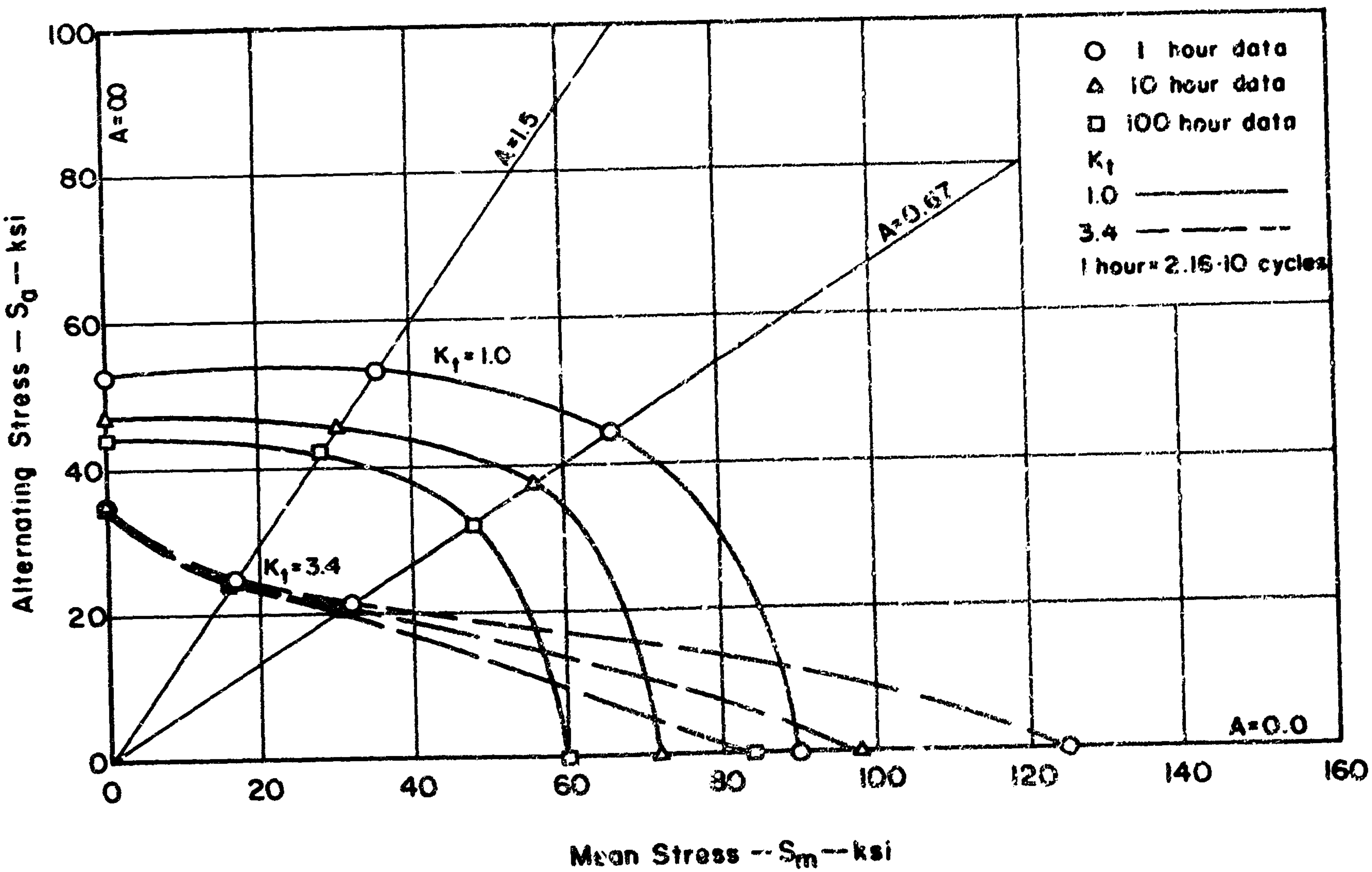


Figure 40 Stress Range Diagram for Unnotched and Notched Specimens of Super A-286 at 1250°F.

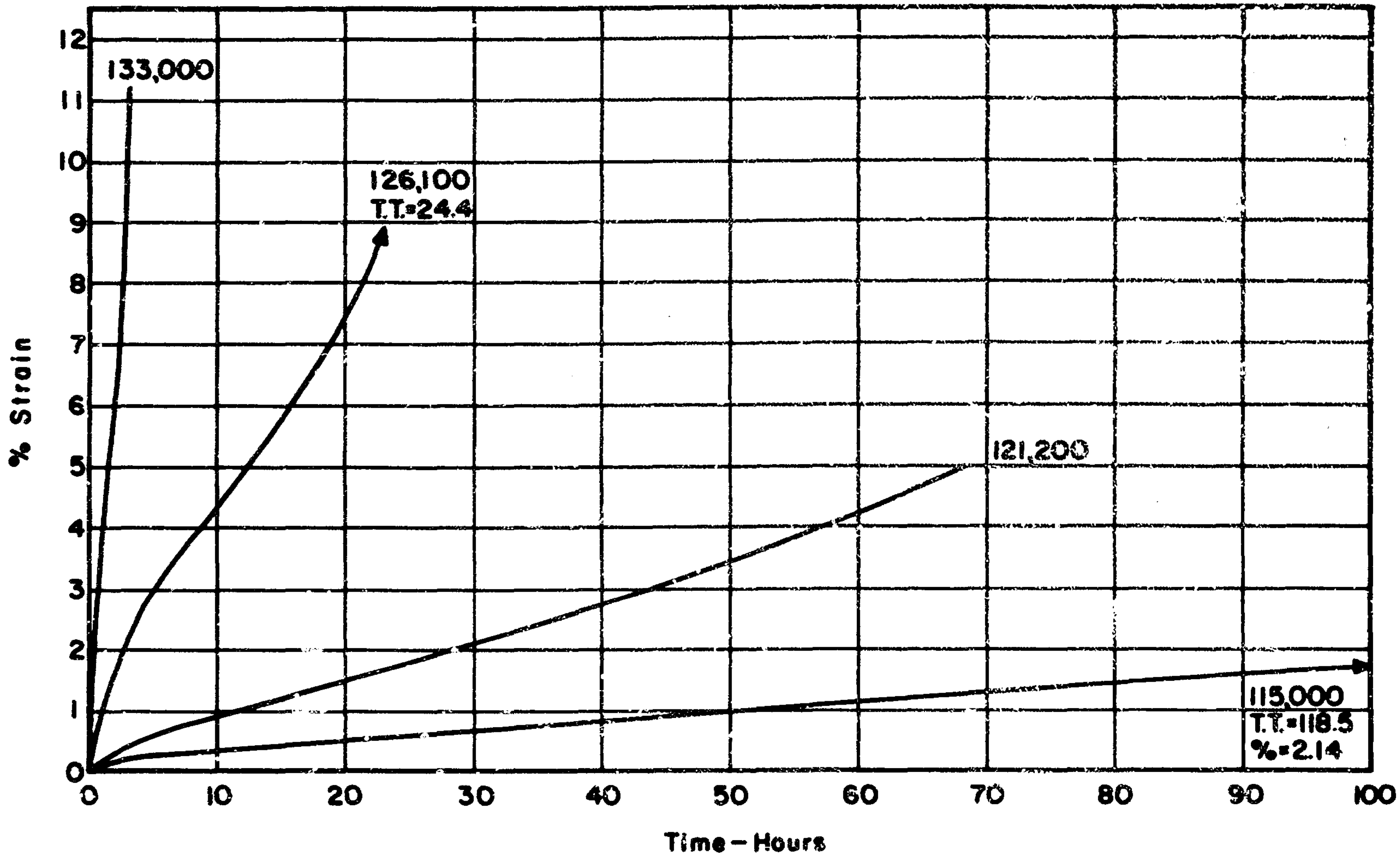


Figure 41 Creep Time Curves for Super A-286 Under Static Load (A = 0) at $1000^{\circ}F$.

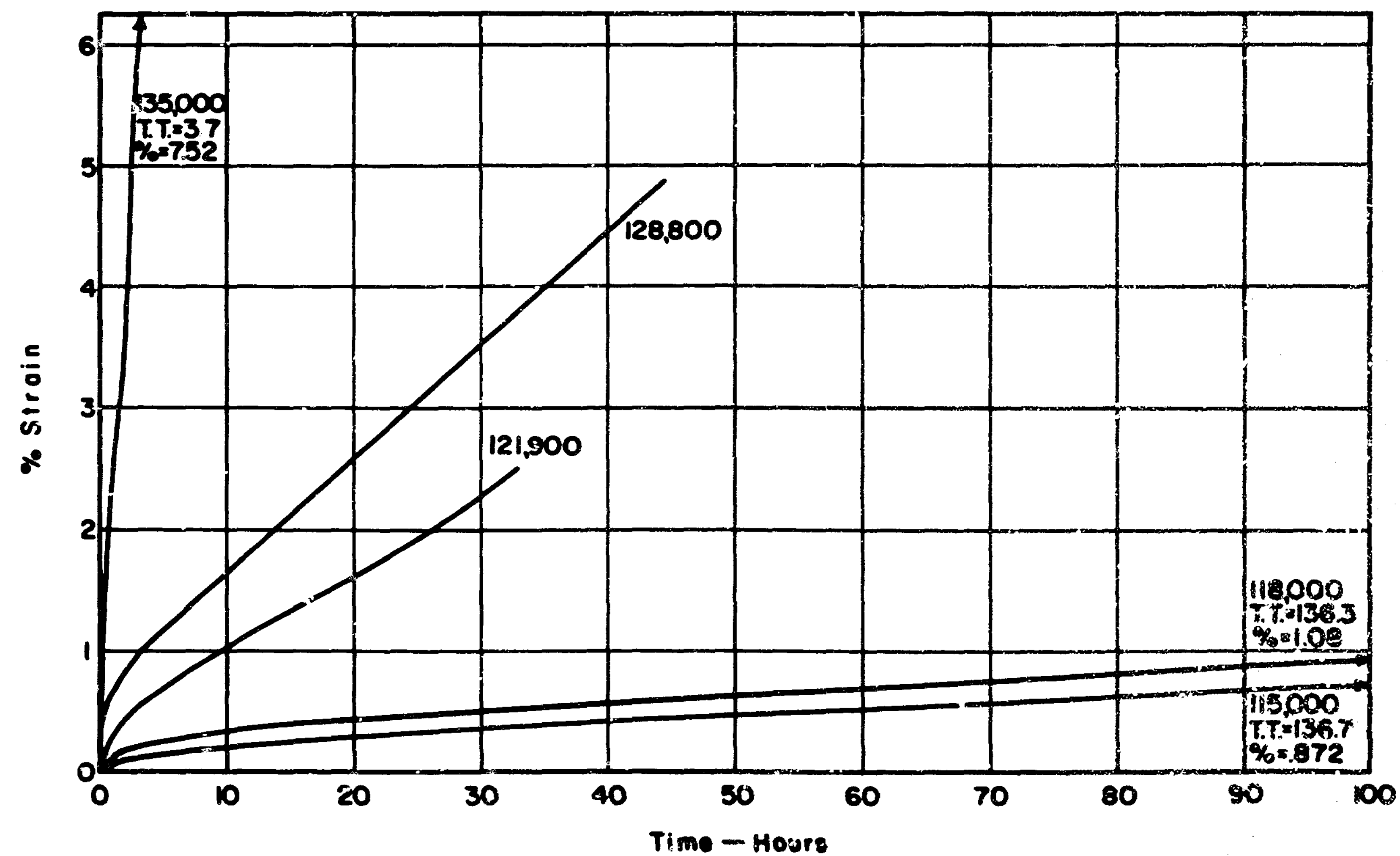


Figure 42 Creep Time Curves for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.15 and at 1000°F.

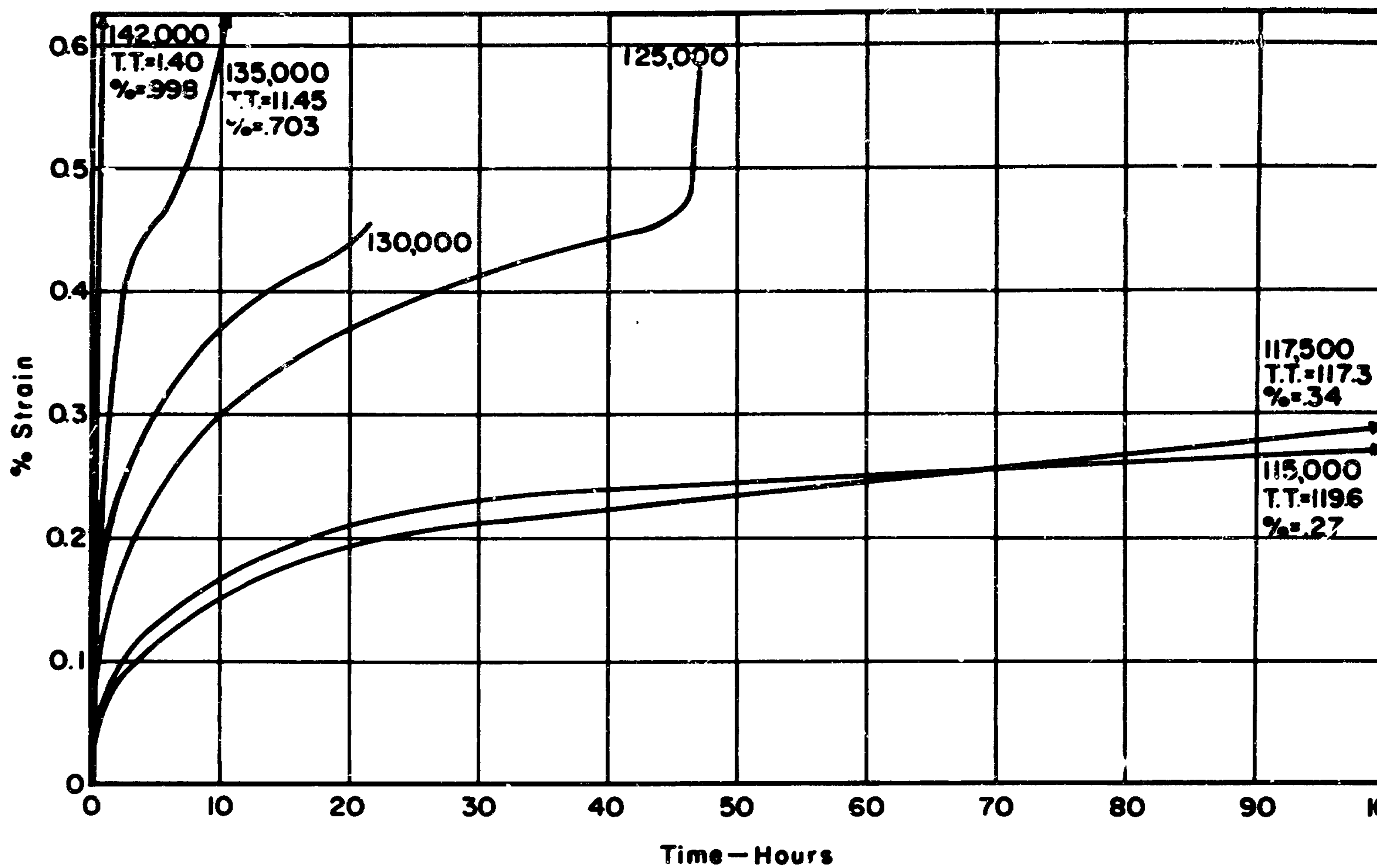


Figure 43 Creep Time Curves for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.35 and at 1000°F.

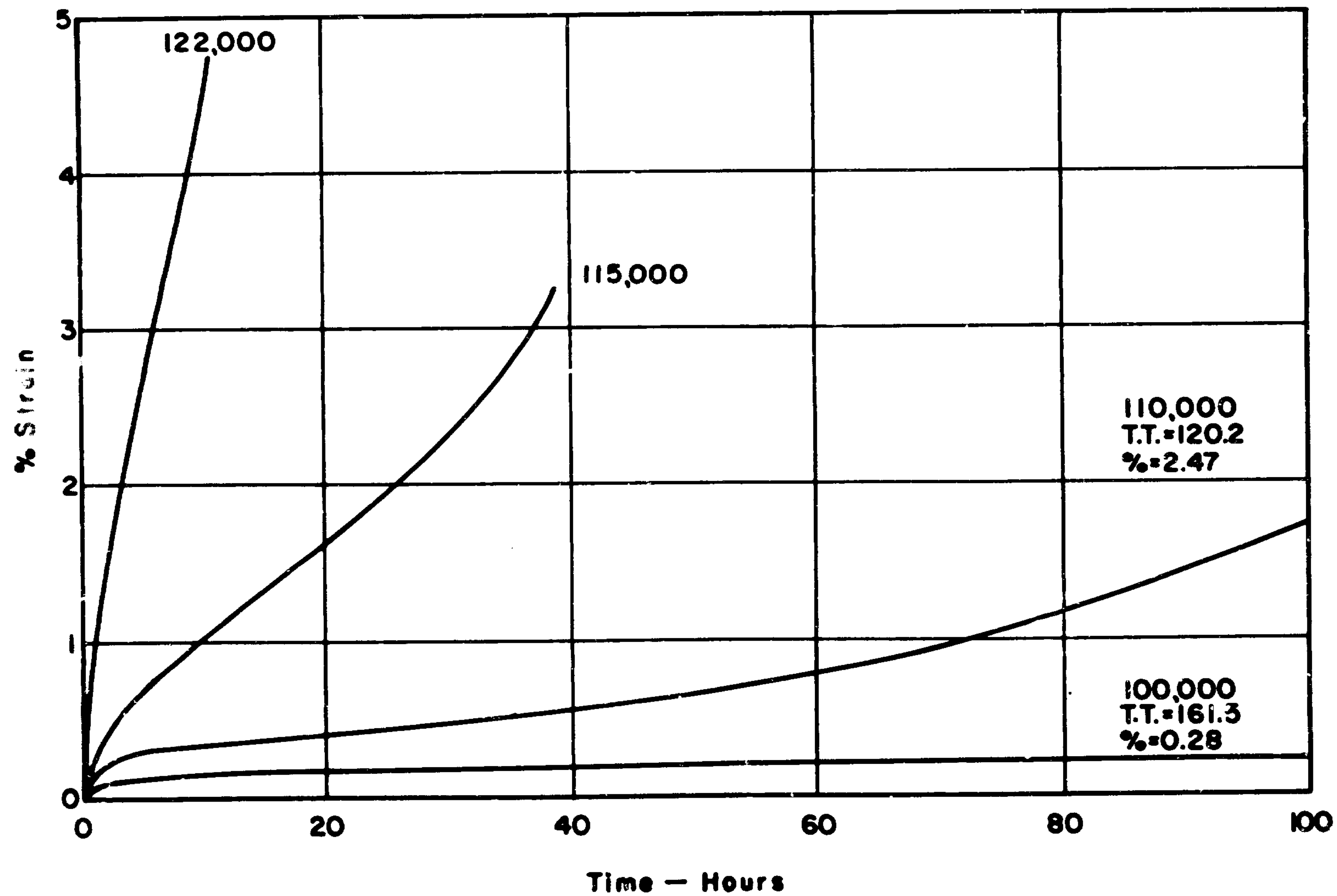


Figure 44 Creep Time Curves for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1100°F.

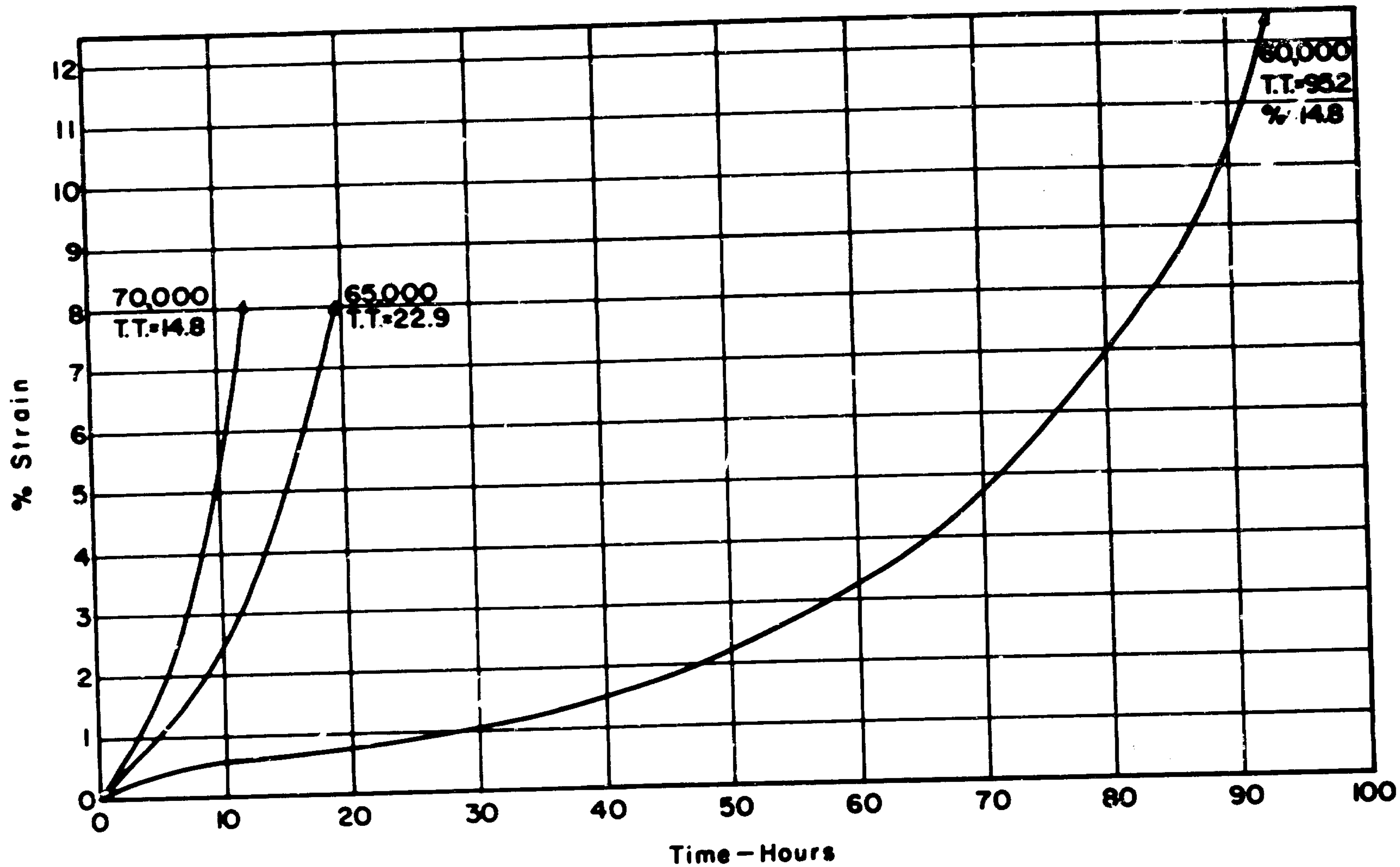


Figure 45 Creep Time Curves for Super A-286 Under Static Load (A = 0) at 1250°F.

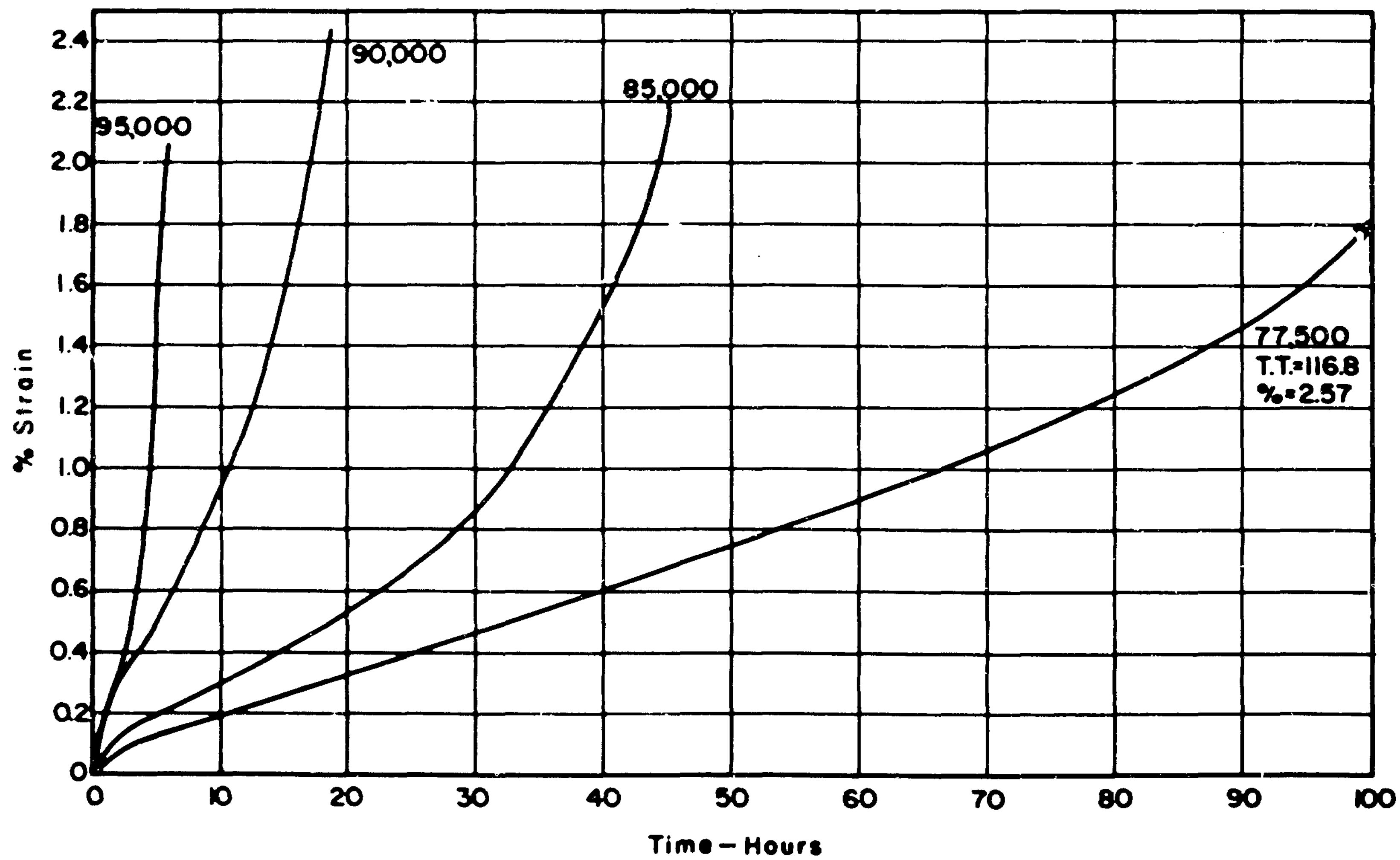


Figure 46 Creep Time Curves for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.67 and at 1250°F.

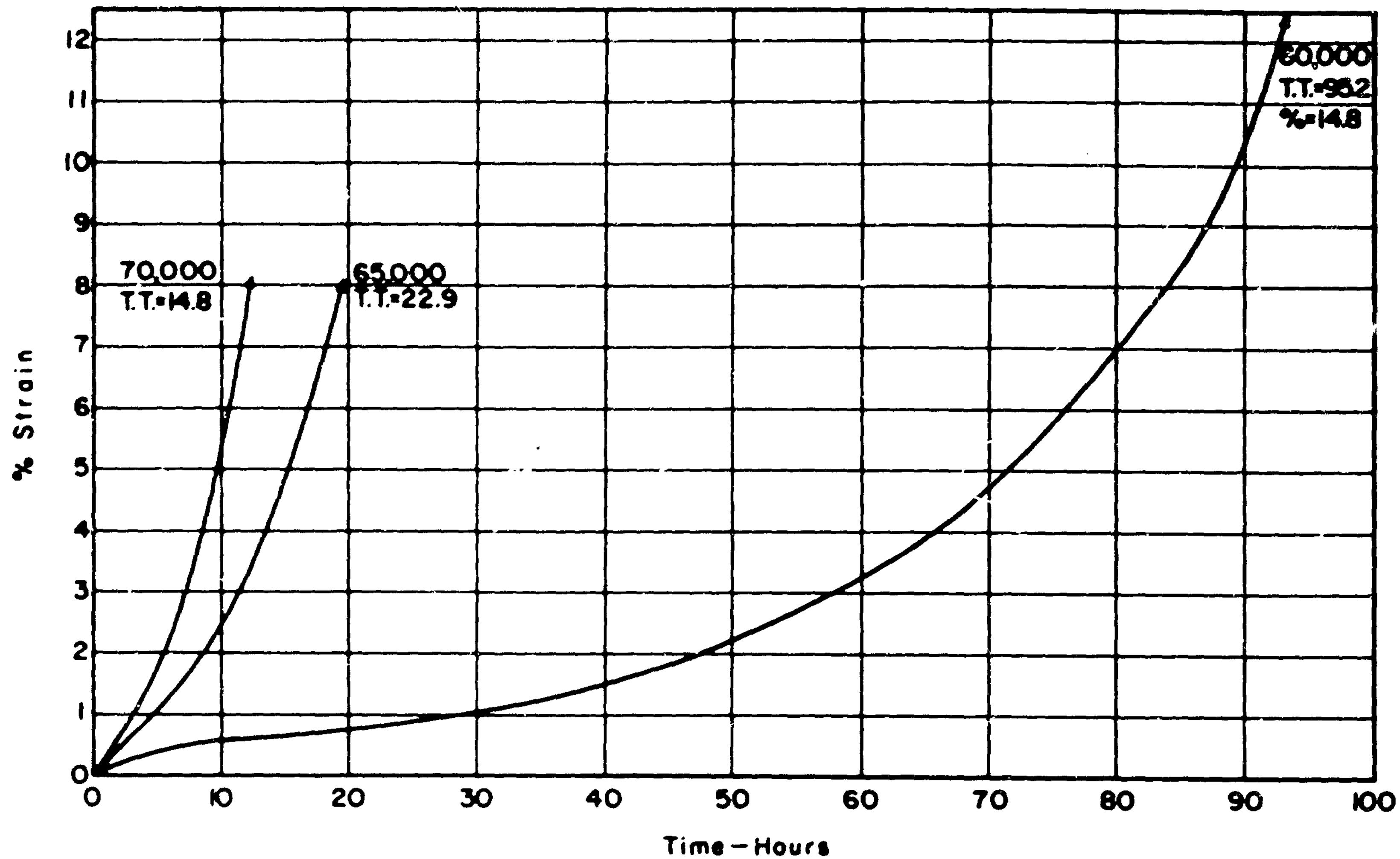


Figure 45 Creep Time Curves for Super A-286 Under Static Load (A = 0) at 1250°F.

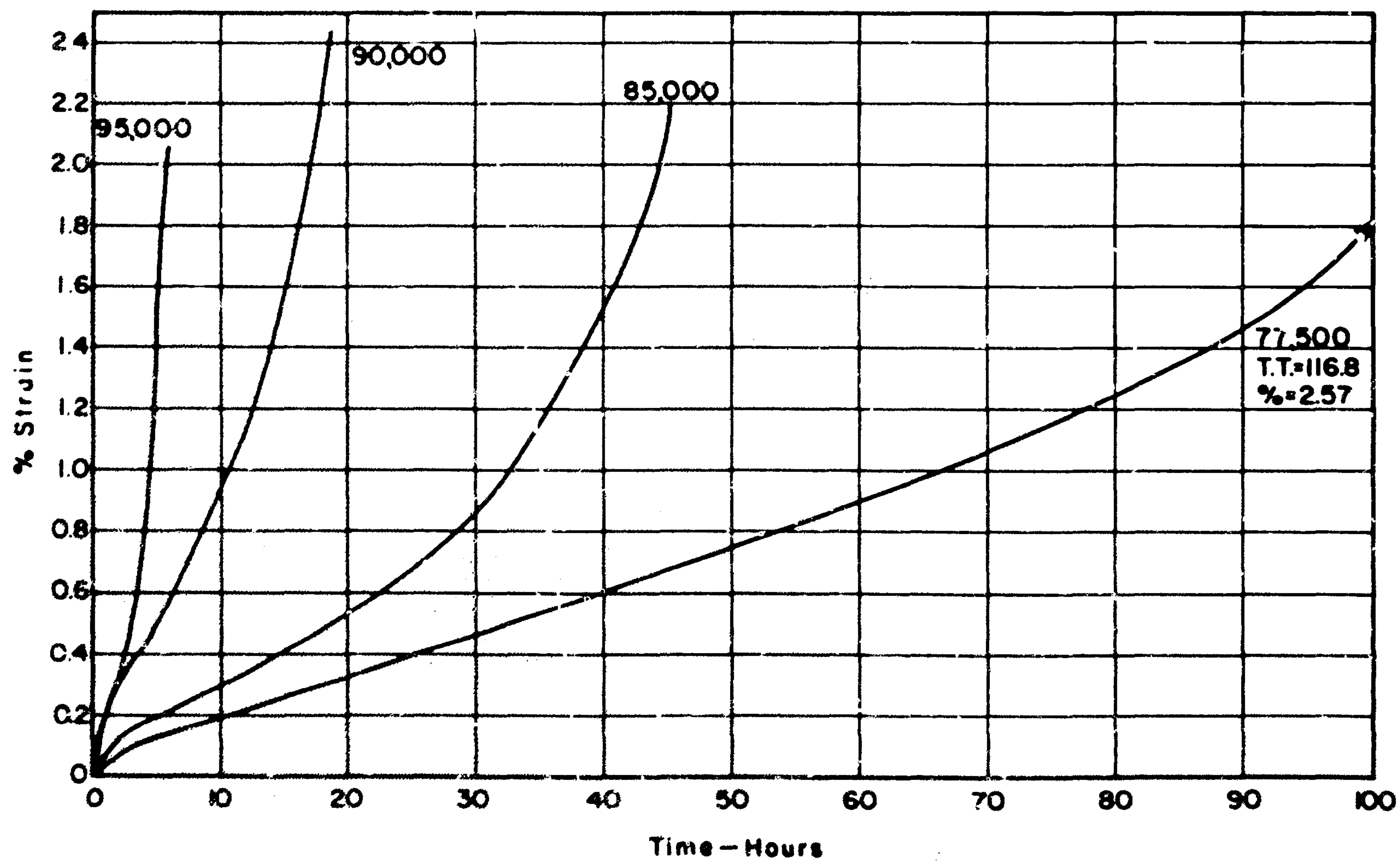


Figure 46 Creep Time Curves for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.67 and at 1250°F.

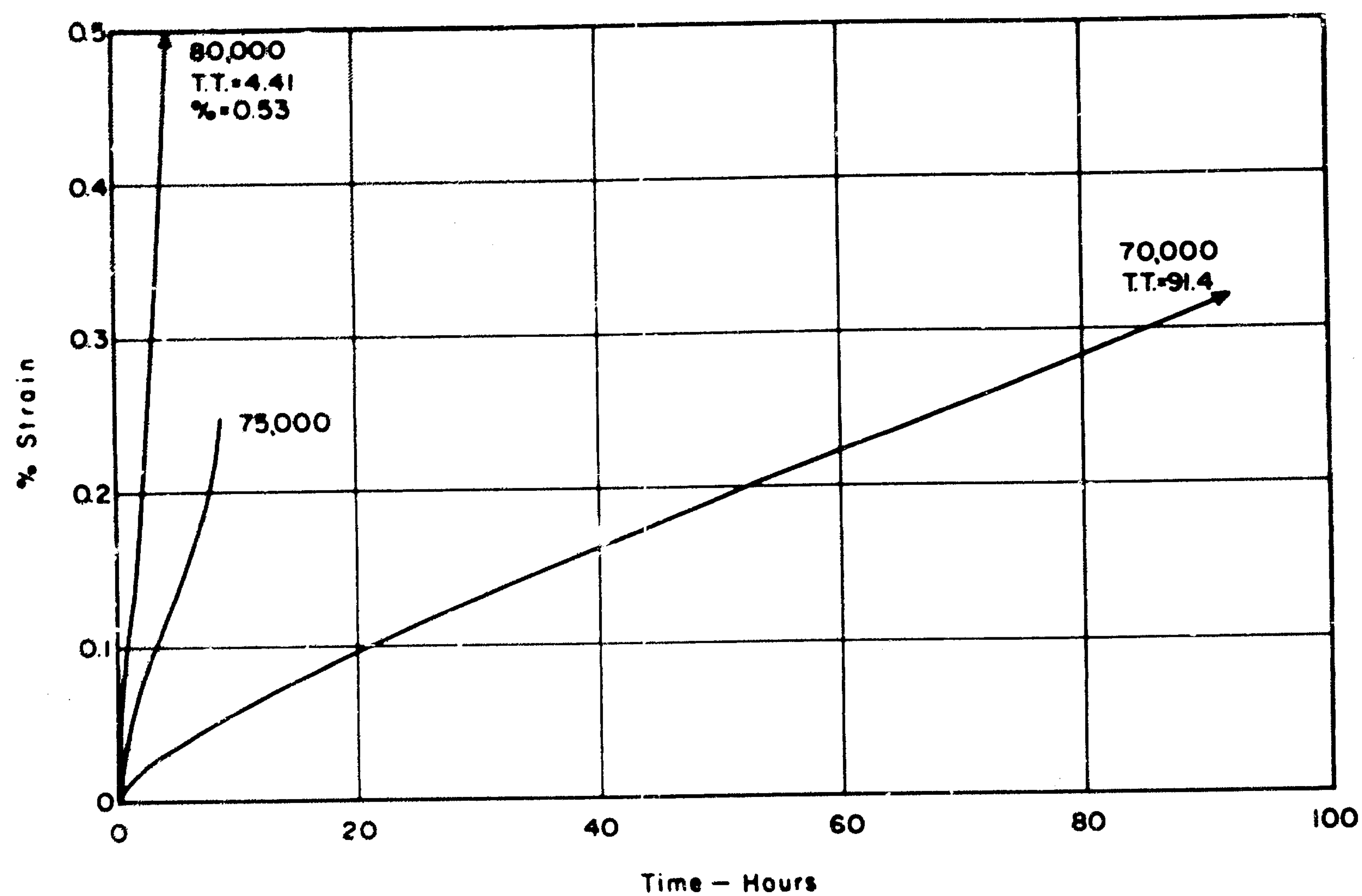


Figure 47 Creep Time Curves for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 1.5 and at 1250°F.

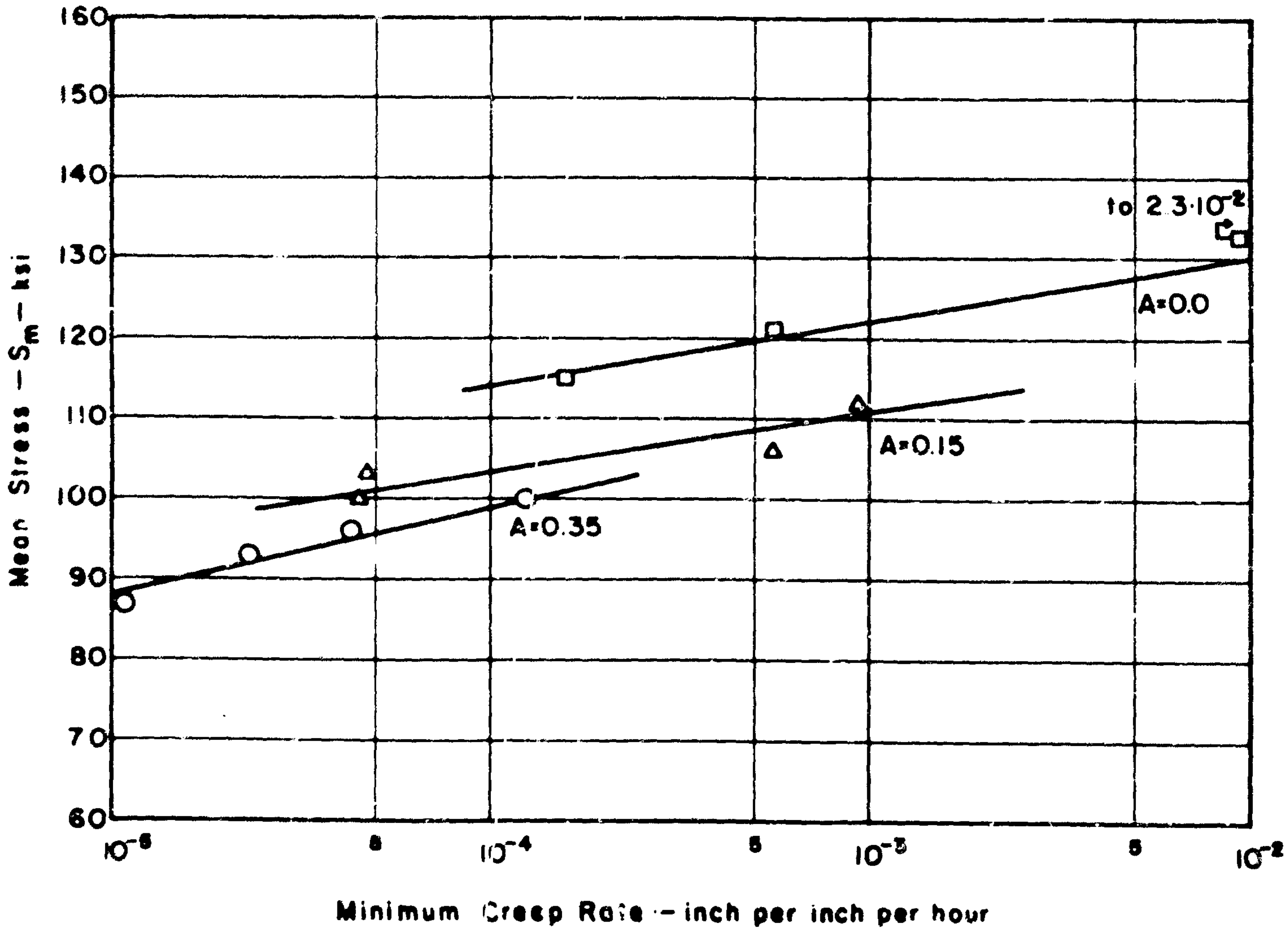


Figure 48 Minimum Creep Rate Versus Mean Stress for Super A-286 at Various Alternating-to-Mean Stress Ratios and at 1000°F.

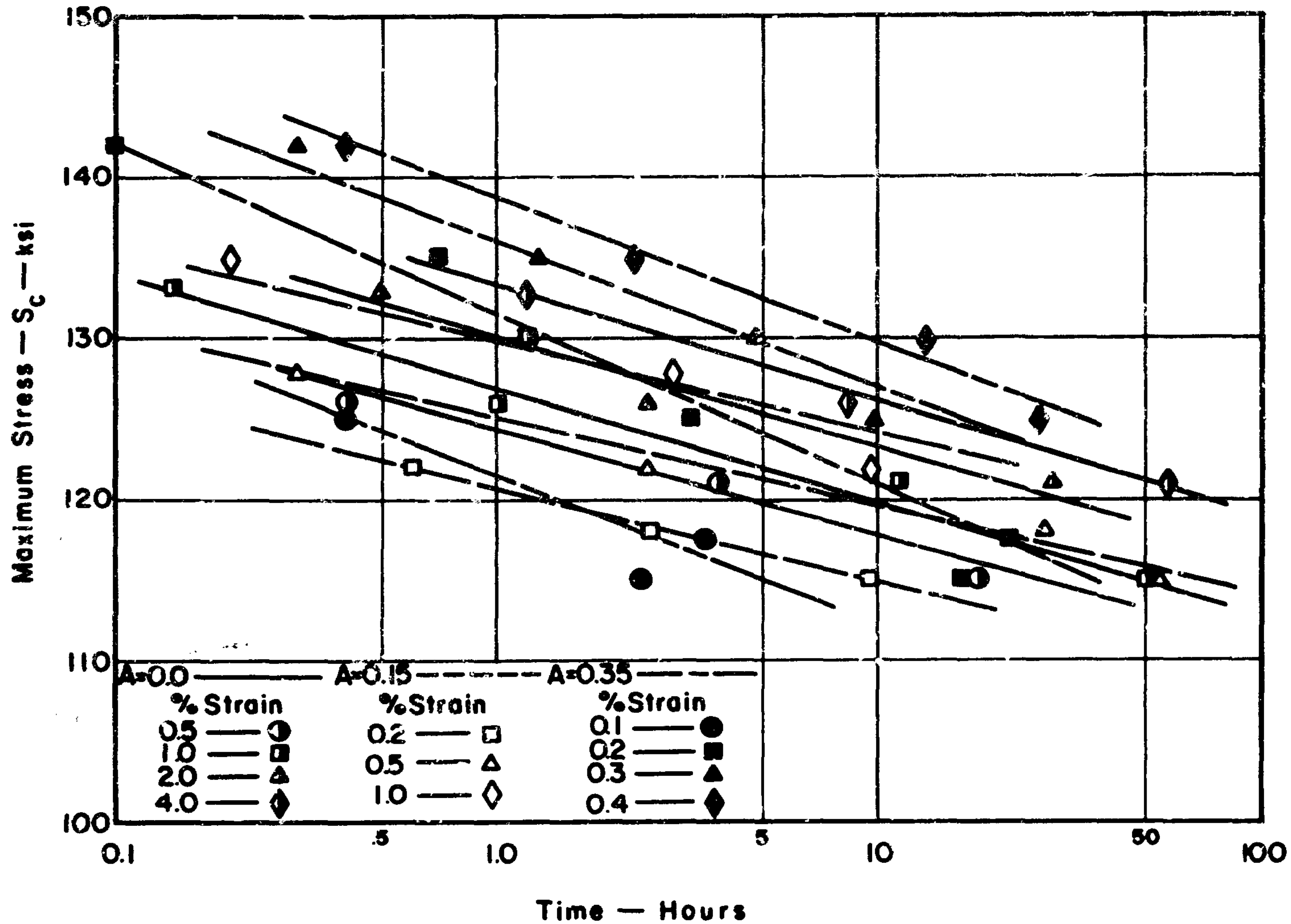


Figure 51 Maximum Stress Versus Time for Various Amounts of Creep for Super A-286 at Alternating-to-Mean Stress Ratios A = 0, 0.15, and 0.35 and at 1000°F.

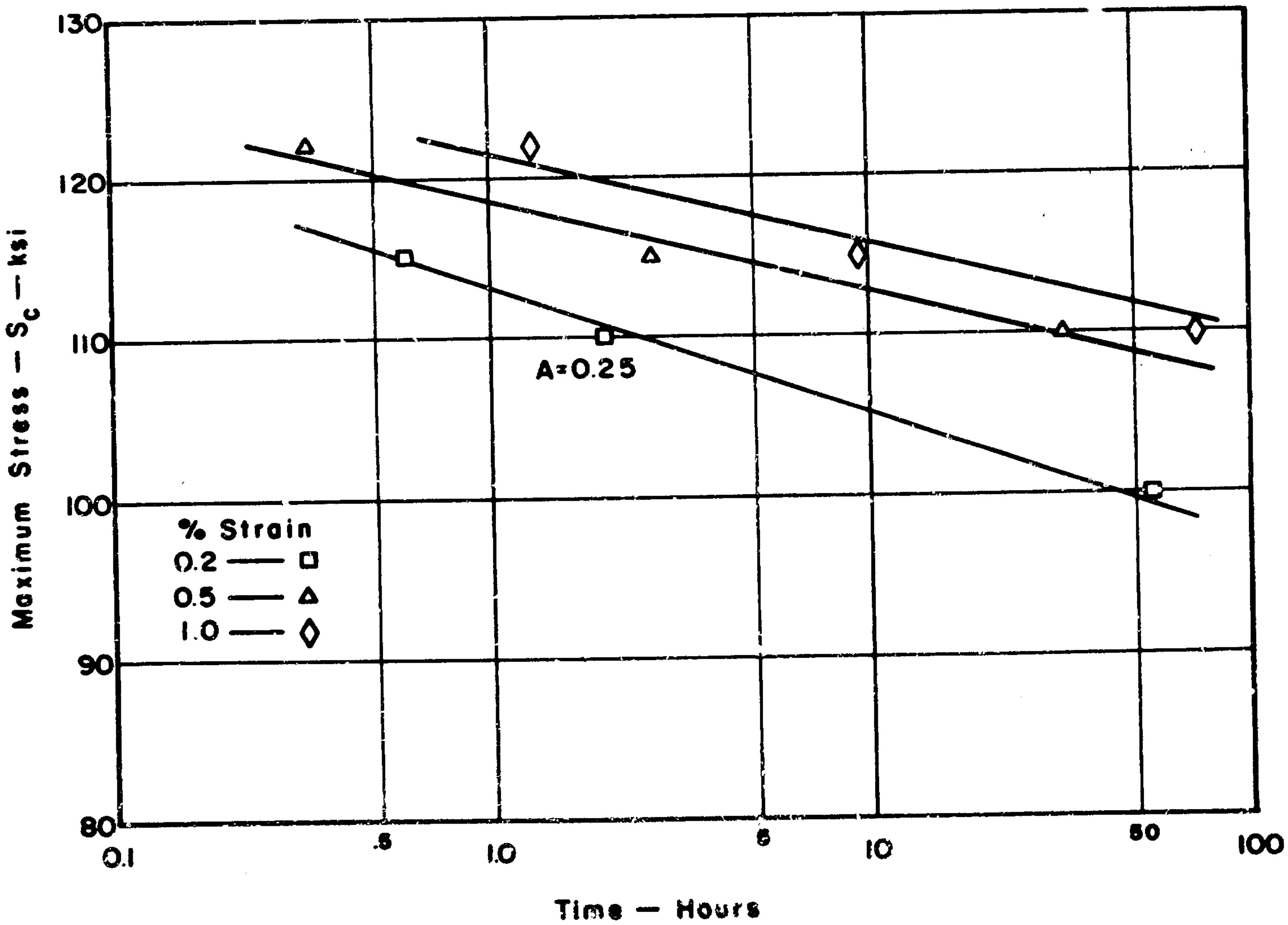


Figure 52 Maximum Stress Versus Time for Various Amounts of Creep for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1100°F.

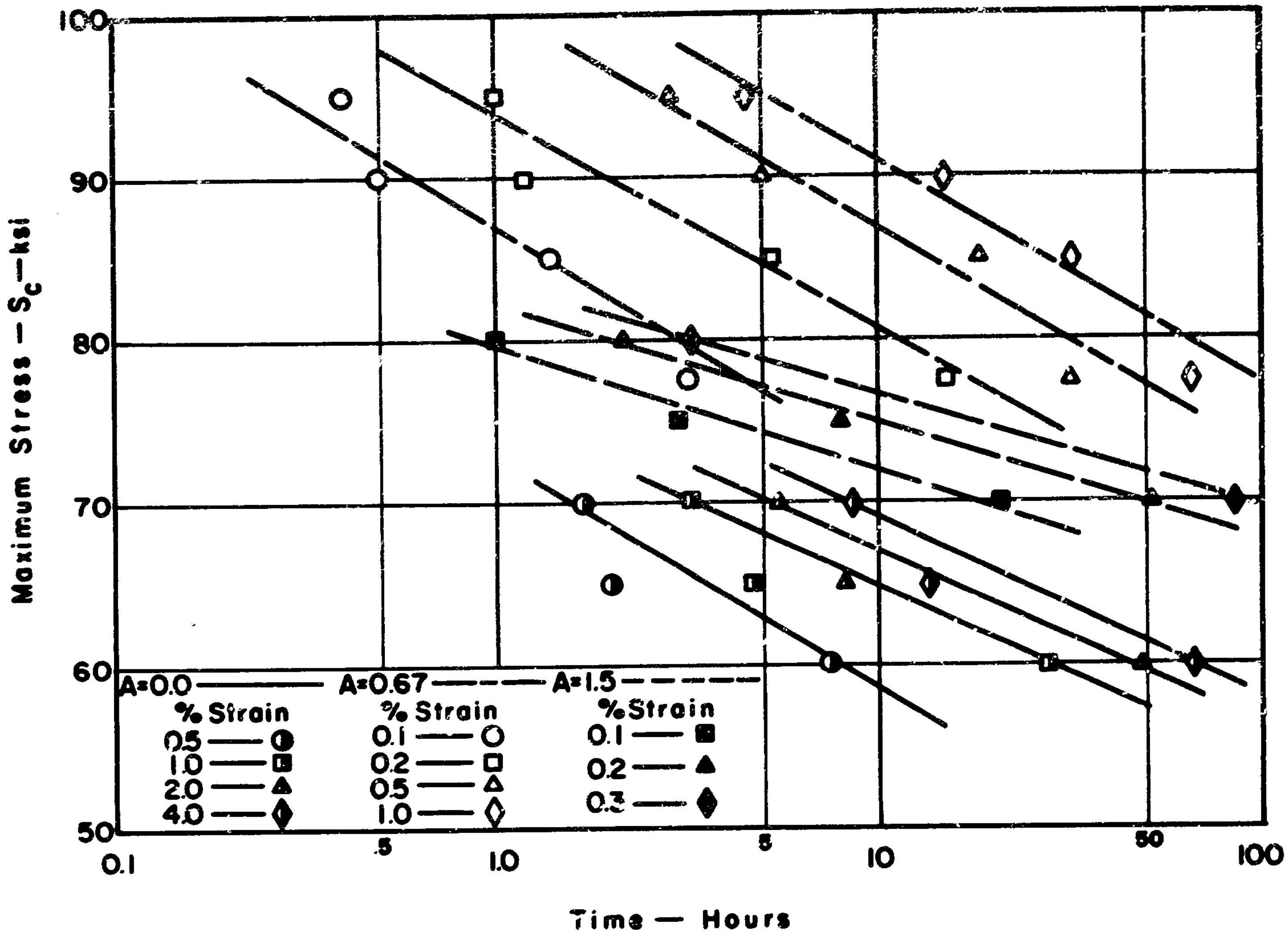


Figure 53 Maximum Stress Versus Time for Various Amounts of Creep for Super A-286 at Alternating-to-Mean Stress Ratios A = 0, 0.67, and 1.5 and at 1250°F.

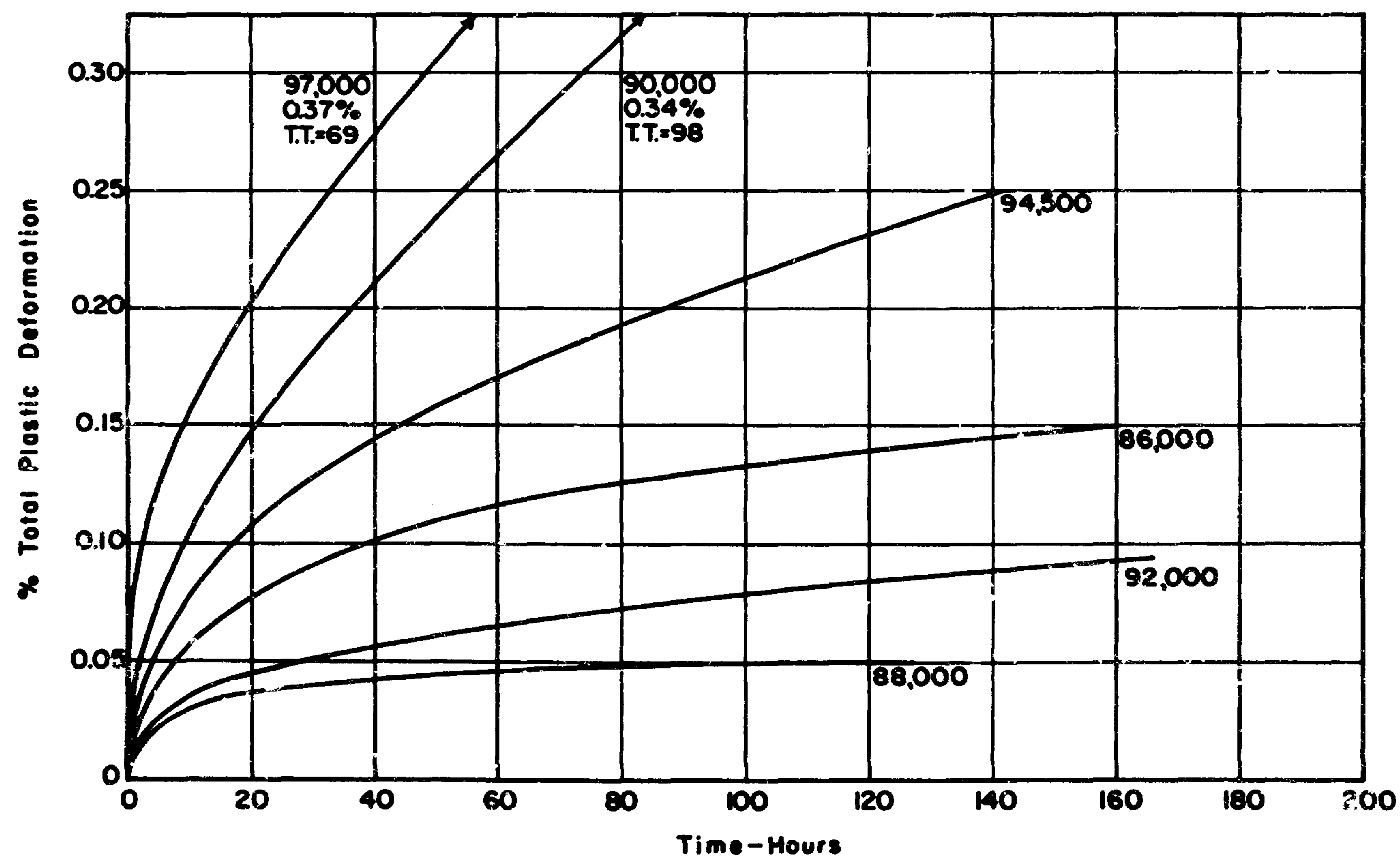


Figure 54 Total Plastic Deformation Versus Time for Super A-286 Under Static Load (A = 0) at 1000°F.

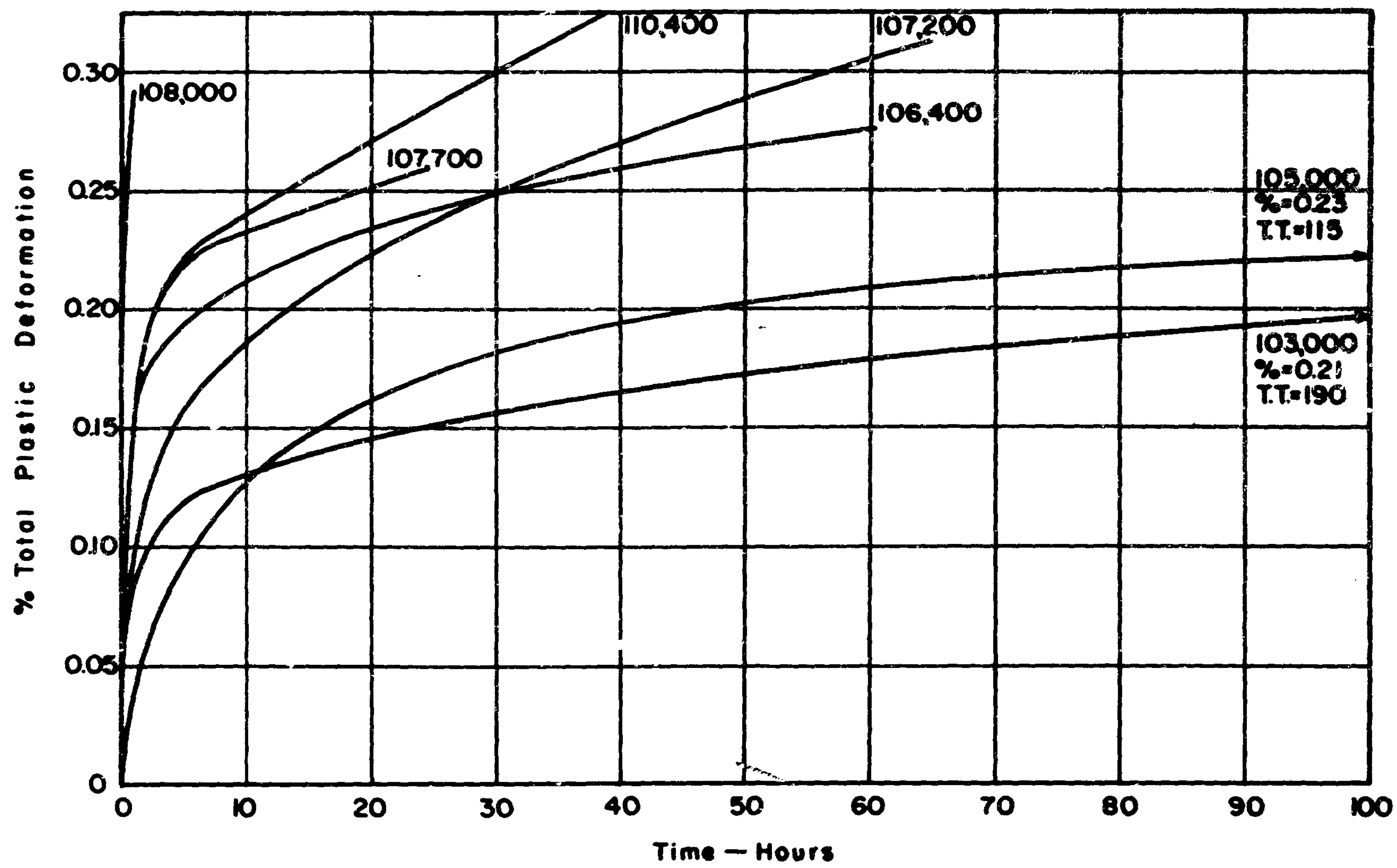


Figure 55 Total Plastic Deformation Versus Time for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.15 and at 1000°F.

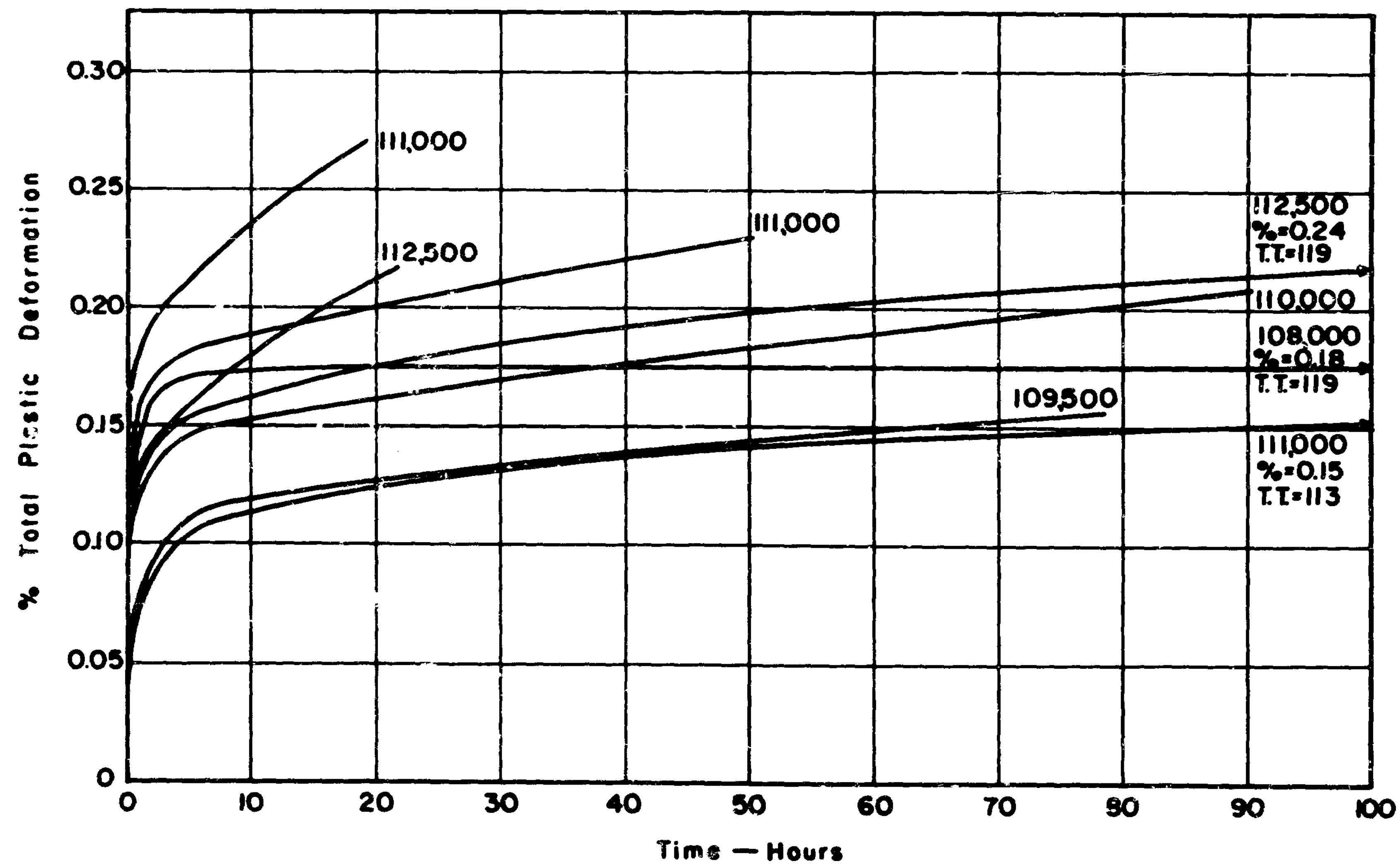


Figure 56 Total Plastic Deformation Versus Time for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.35 and at 1000°F.

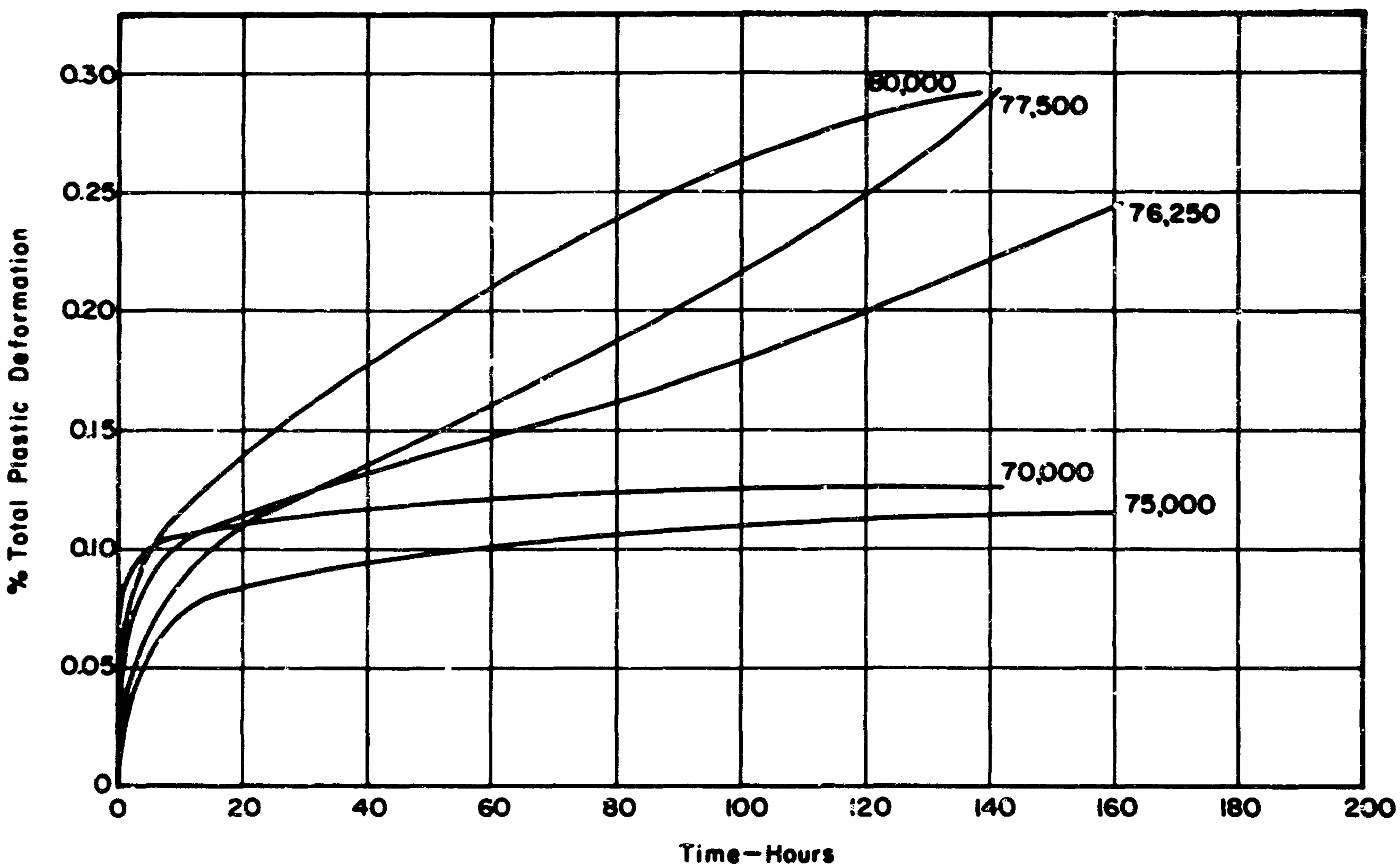


Figure 57 Total Plastic Deformation Versus Time for Super A-286 Under Static Load (A = 0) at 1100°F.

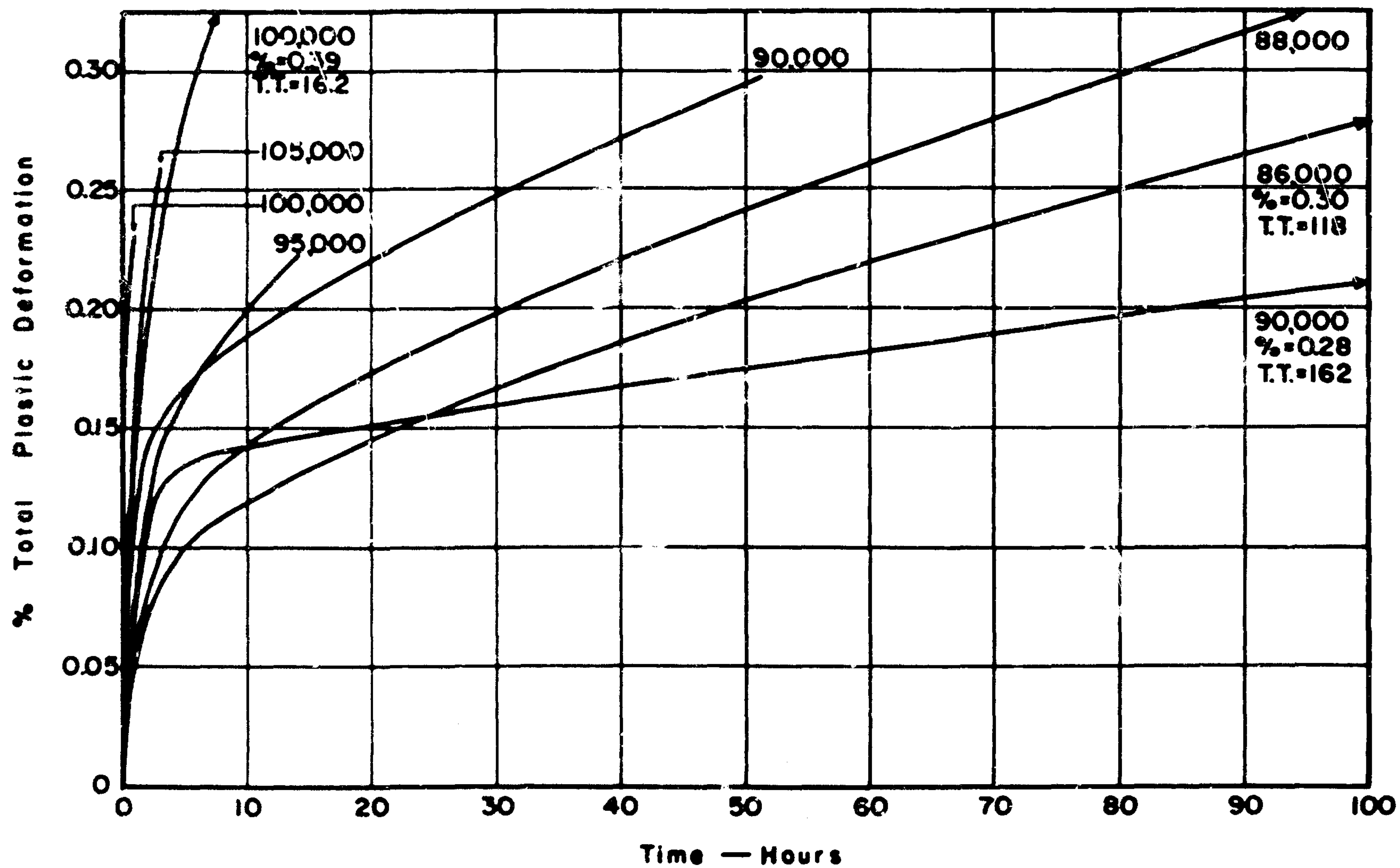


Figure 58 Total Plastic Deformation Versus Time for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.10 and at 1100°F.

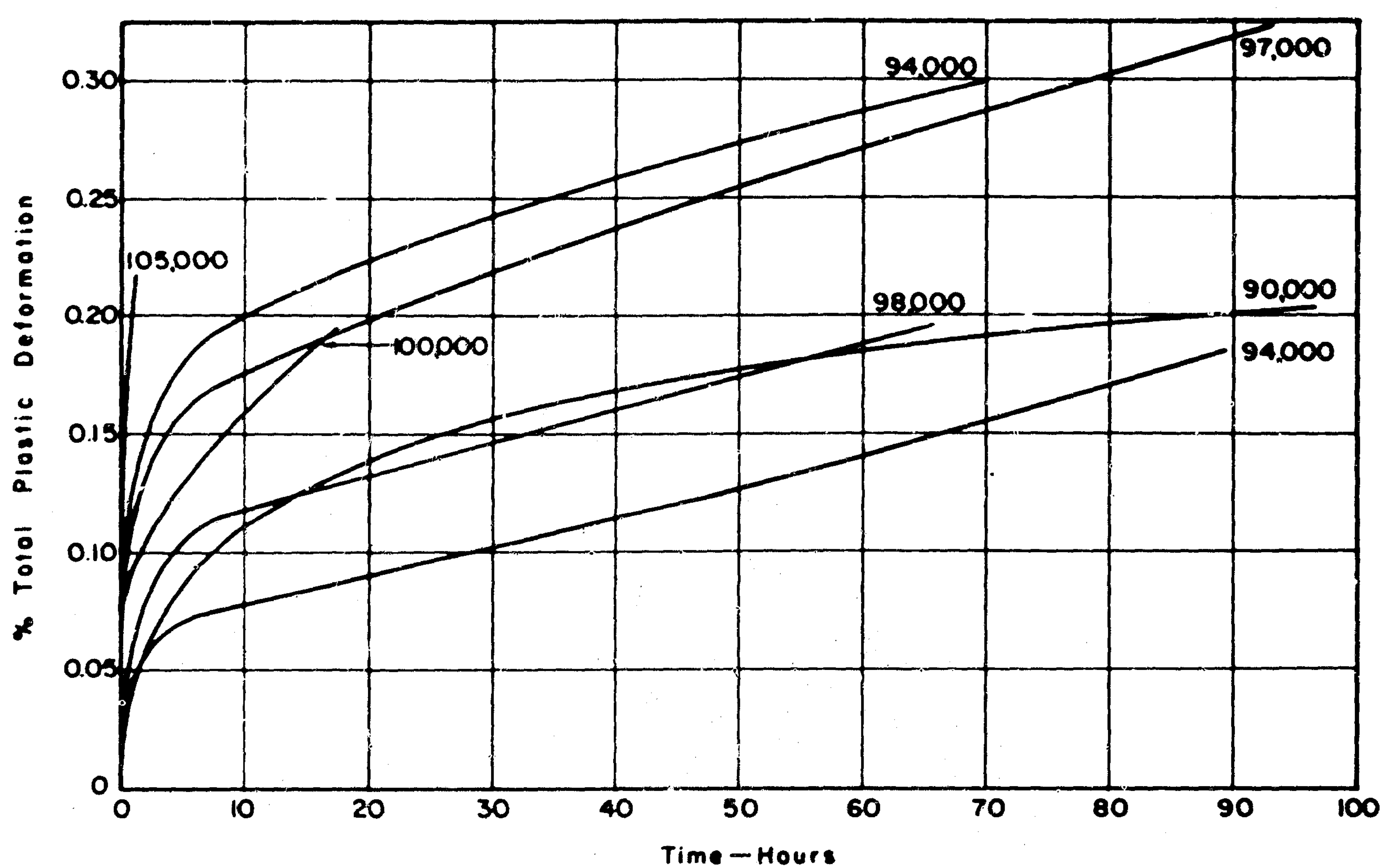


Figure 59 Total Plastic Deformation Versus Time for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1100°F.

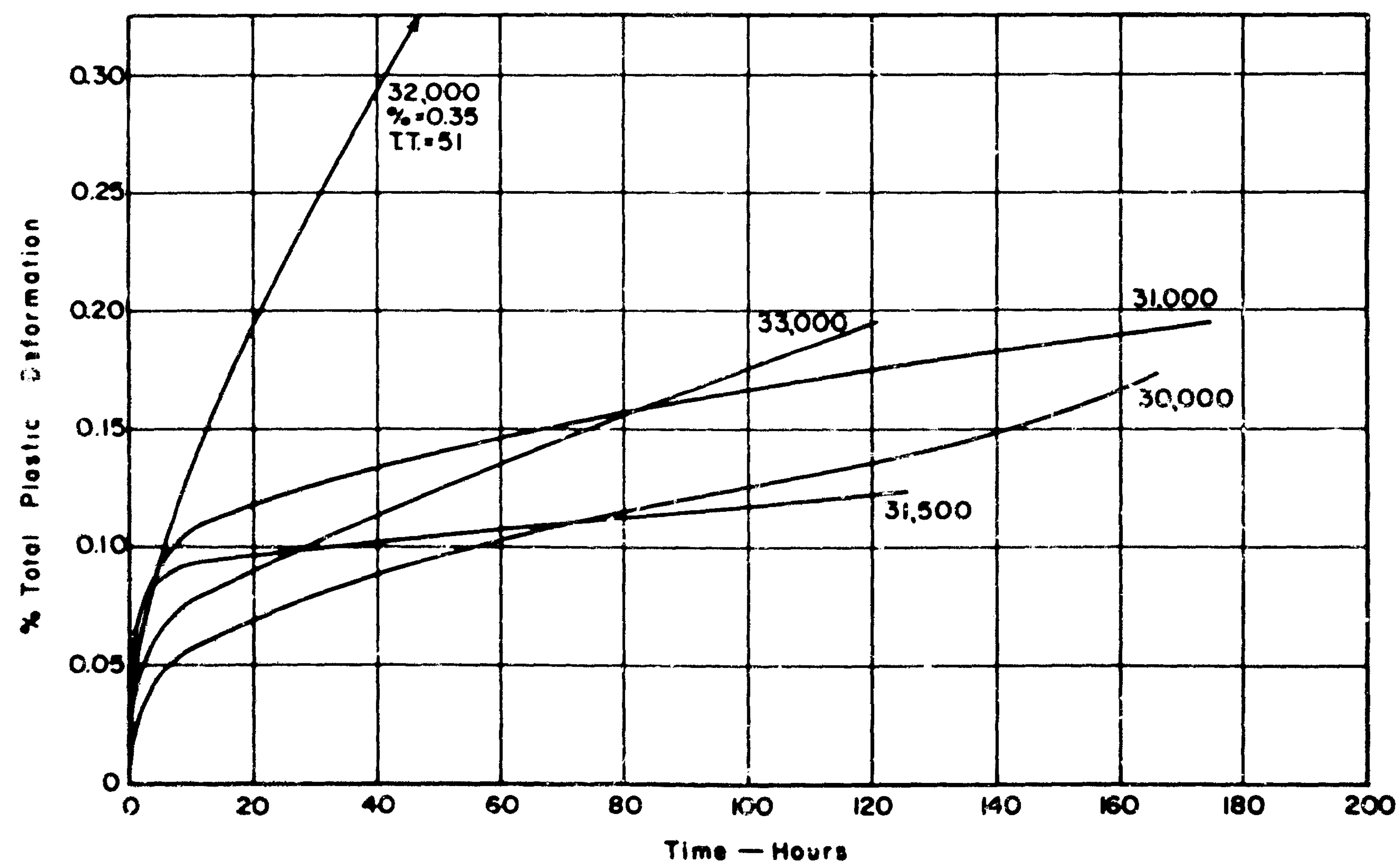


Figure 60 Total Plastic Deformation Versus Time for Super A-286 Under Static Load (A = 0) at 1250°F.

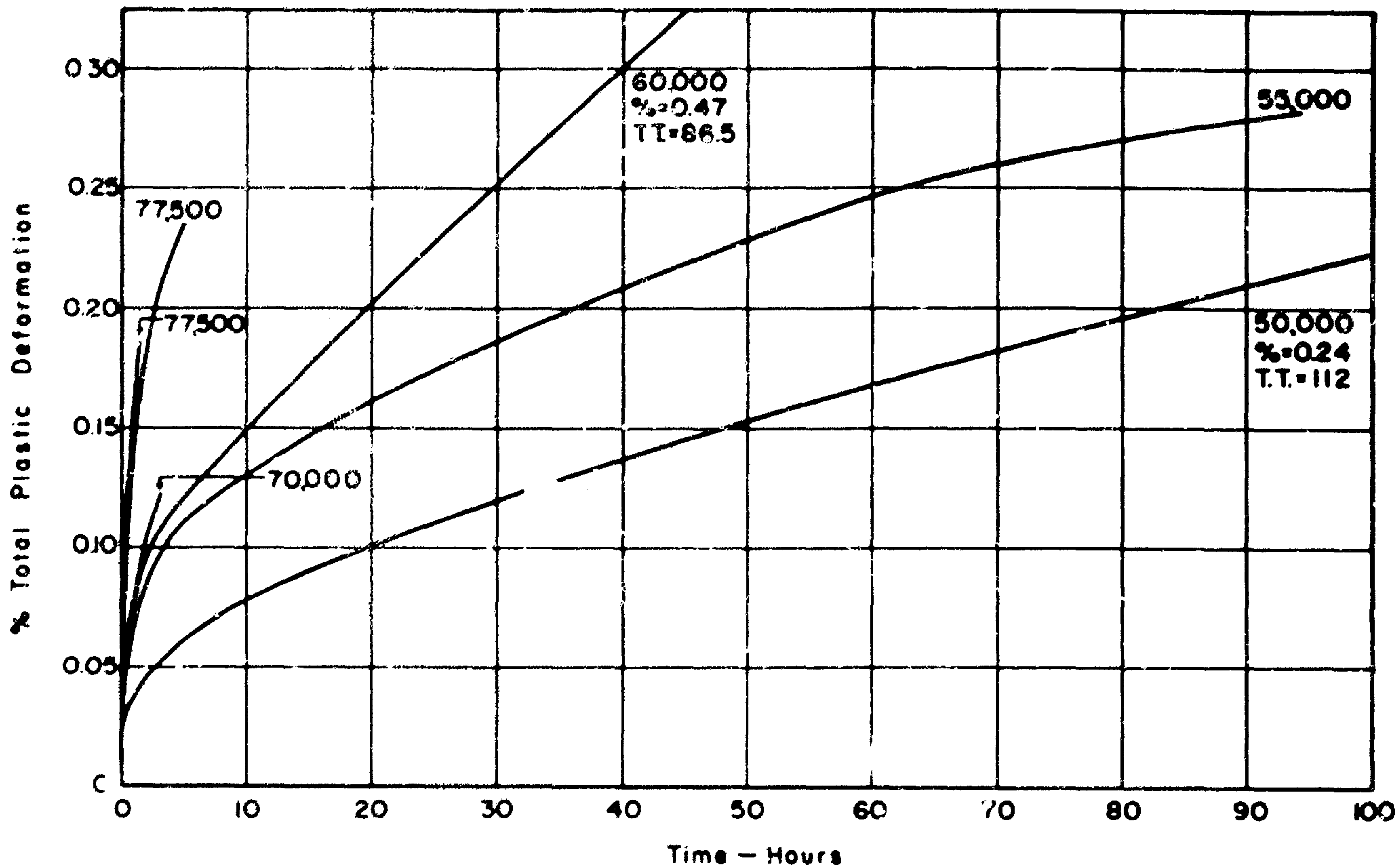


Figure 61 Total Plastic Deformation Versus Time for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.67 and at 1250°F.

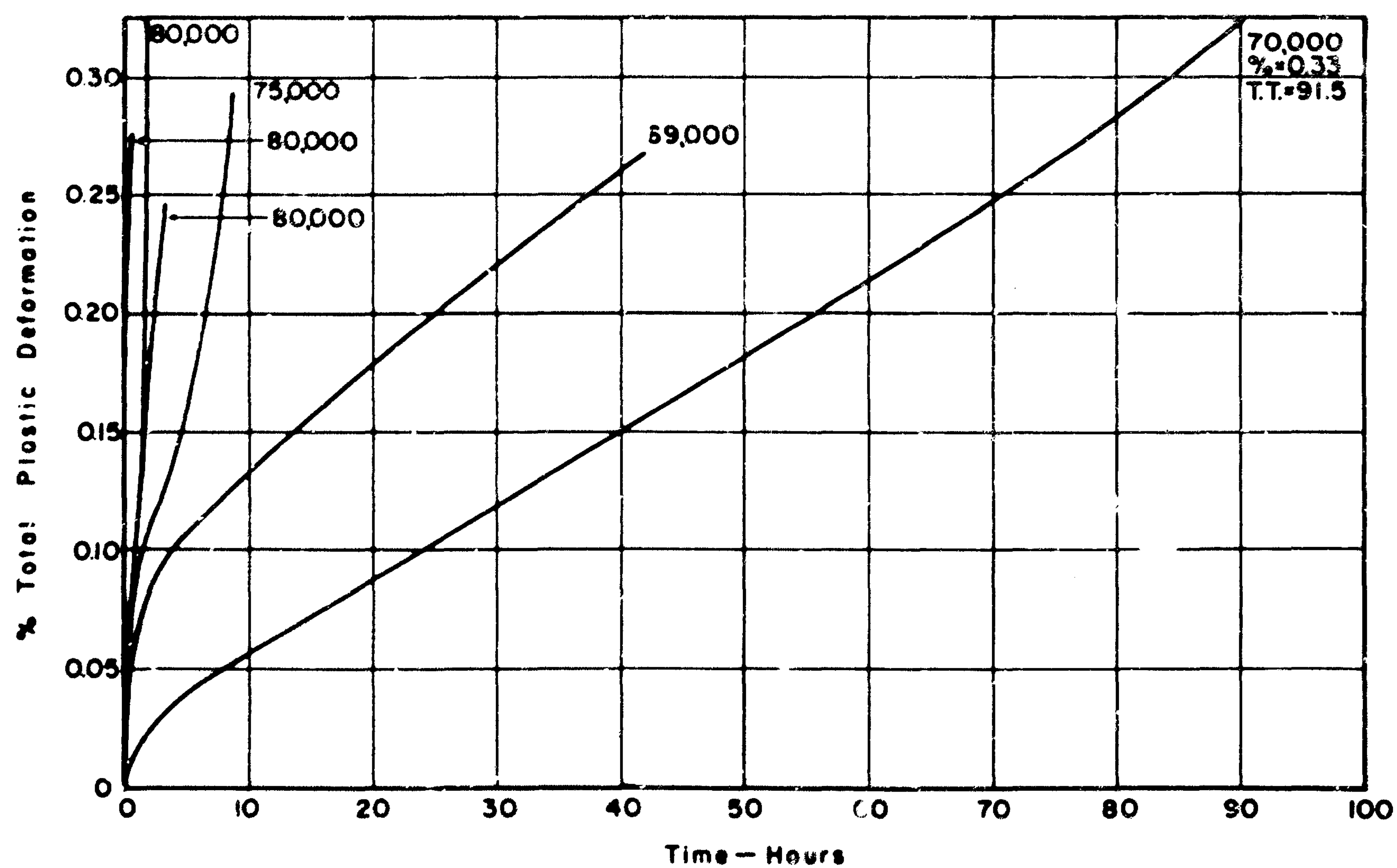


Figure 62 Total Plastic Deformation Versus Time for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 1.5 and at 1250°F.

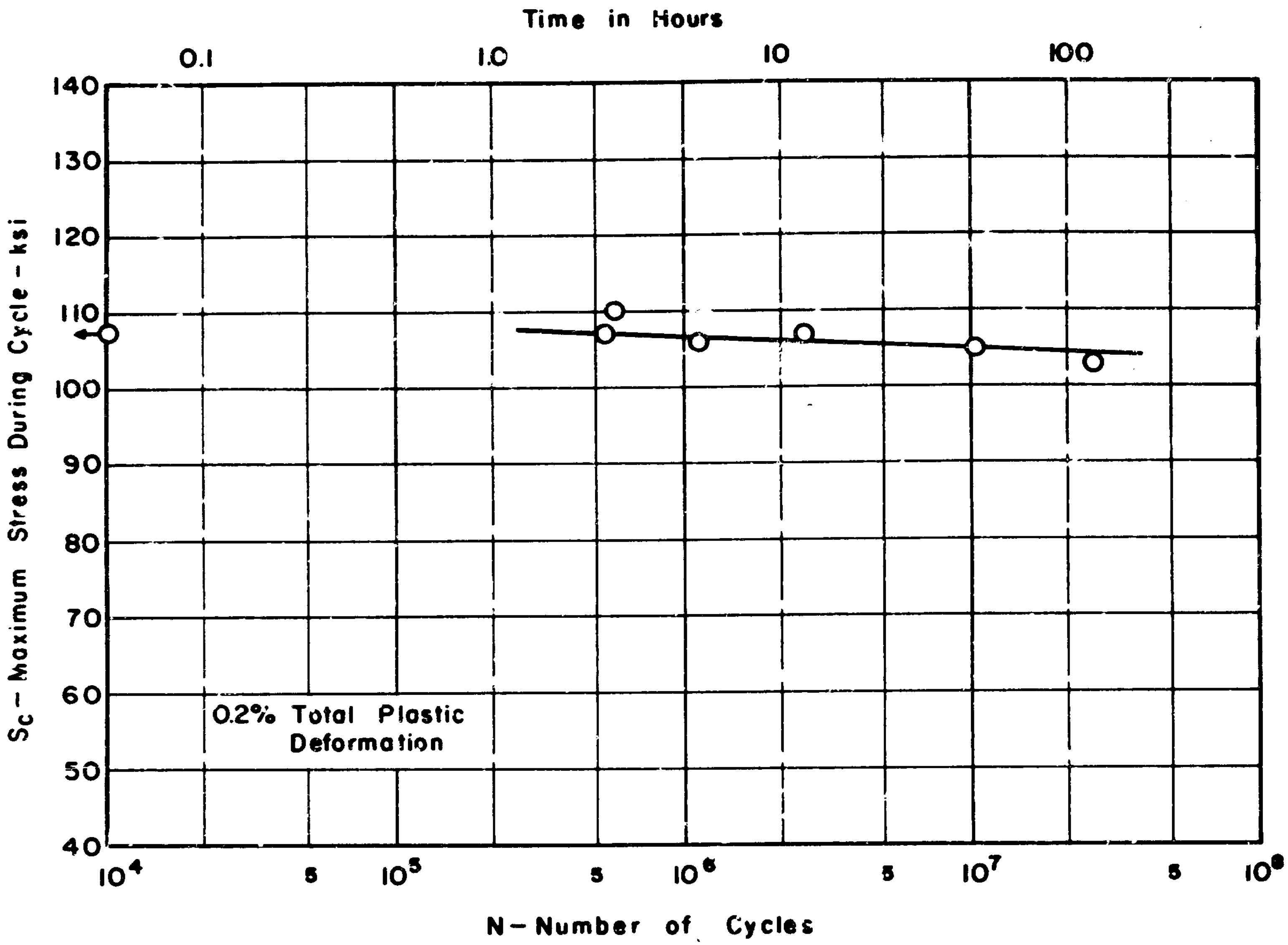


Figure 63 0.2% Total Plastic Deformation for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.15 and at 1000°F.

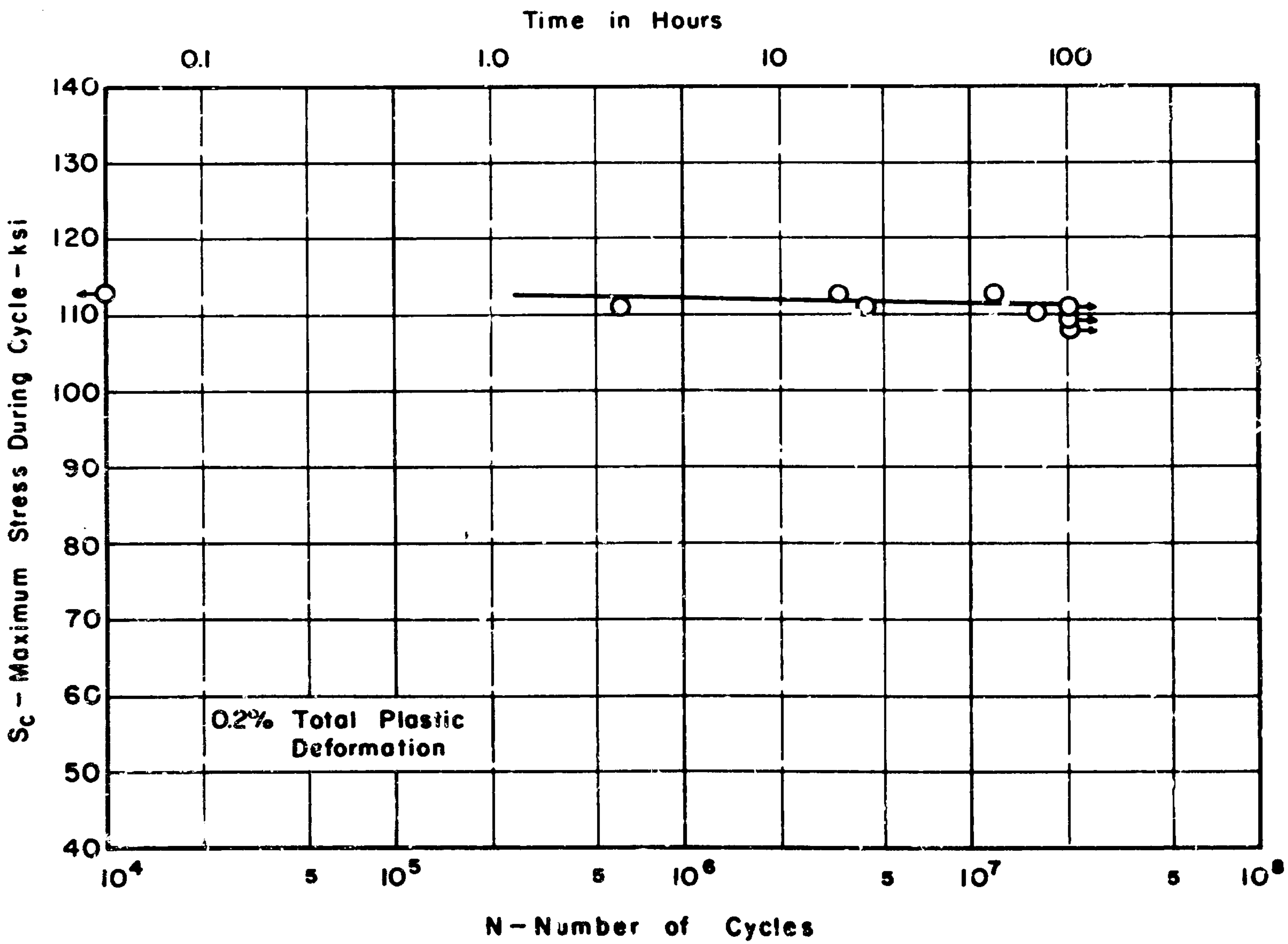


Figure 64 0.2% Total Plastic Deformation for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.35 and at 1000°F.

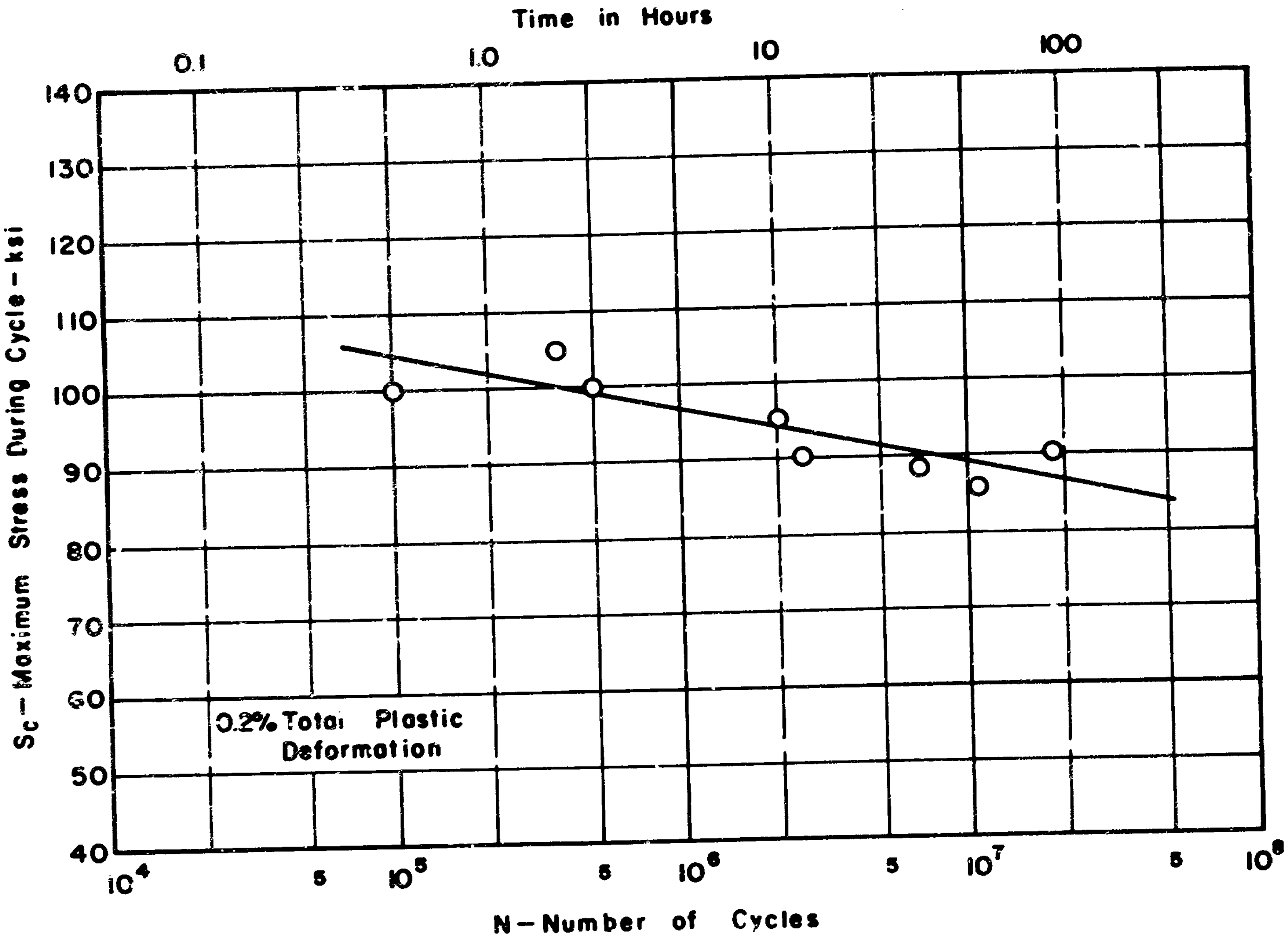


Figure 65 0.2% Total Plastic Deformation for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.10 and at 1100°F.

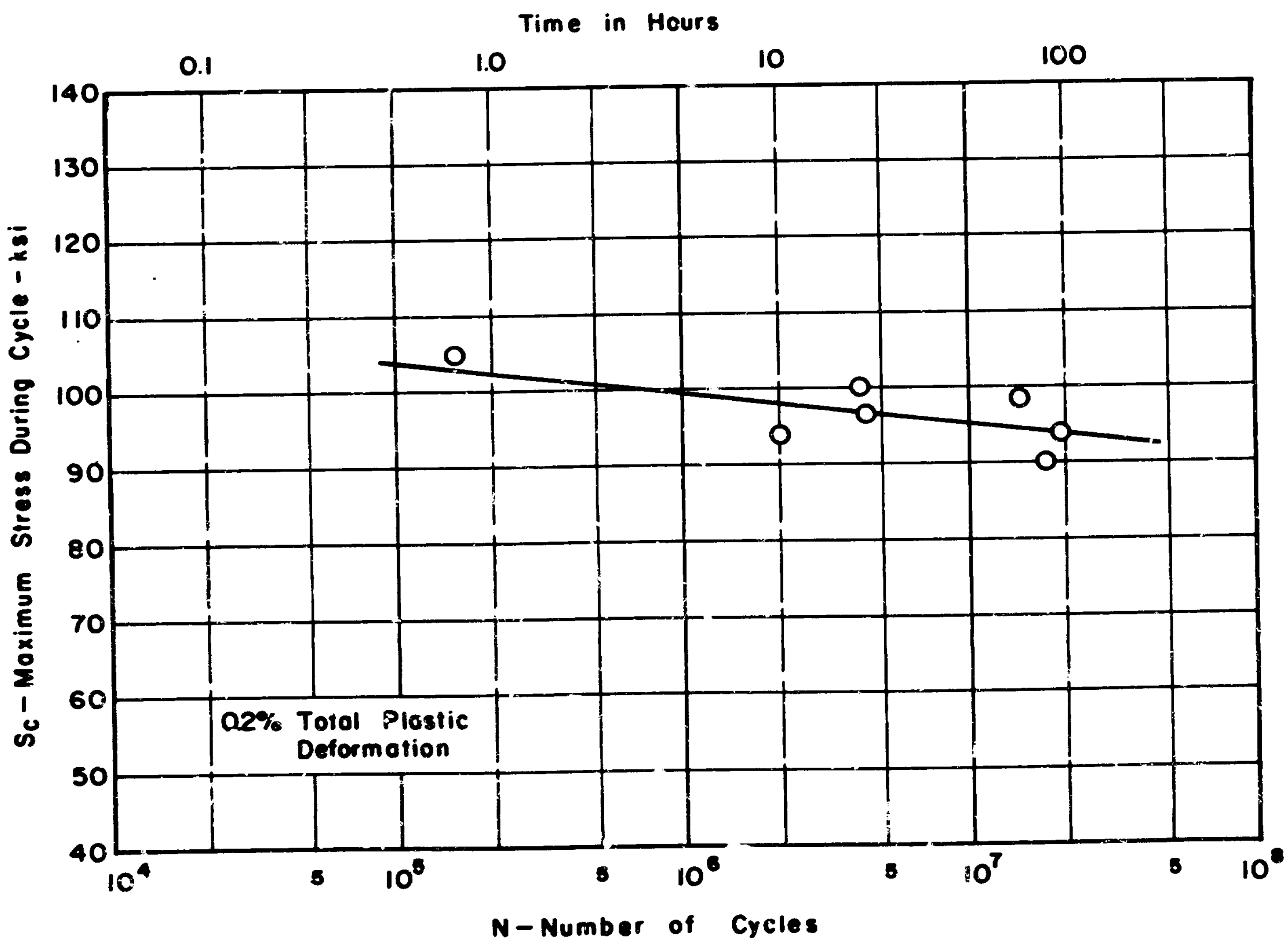


Figure 66 0.2% Total Plastic Deformation for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1100°F.

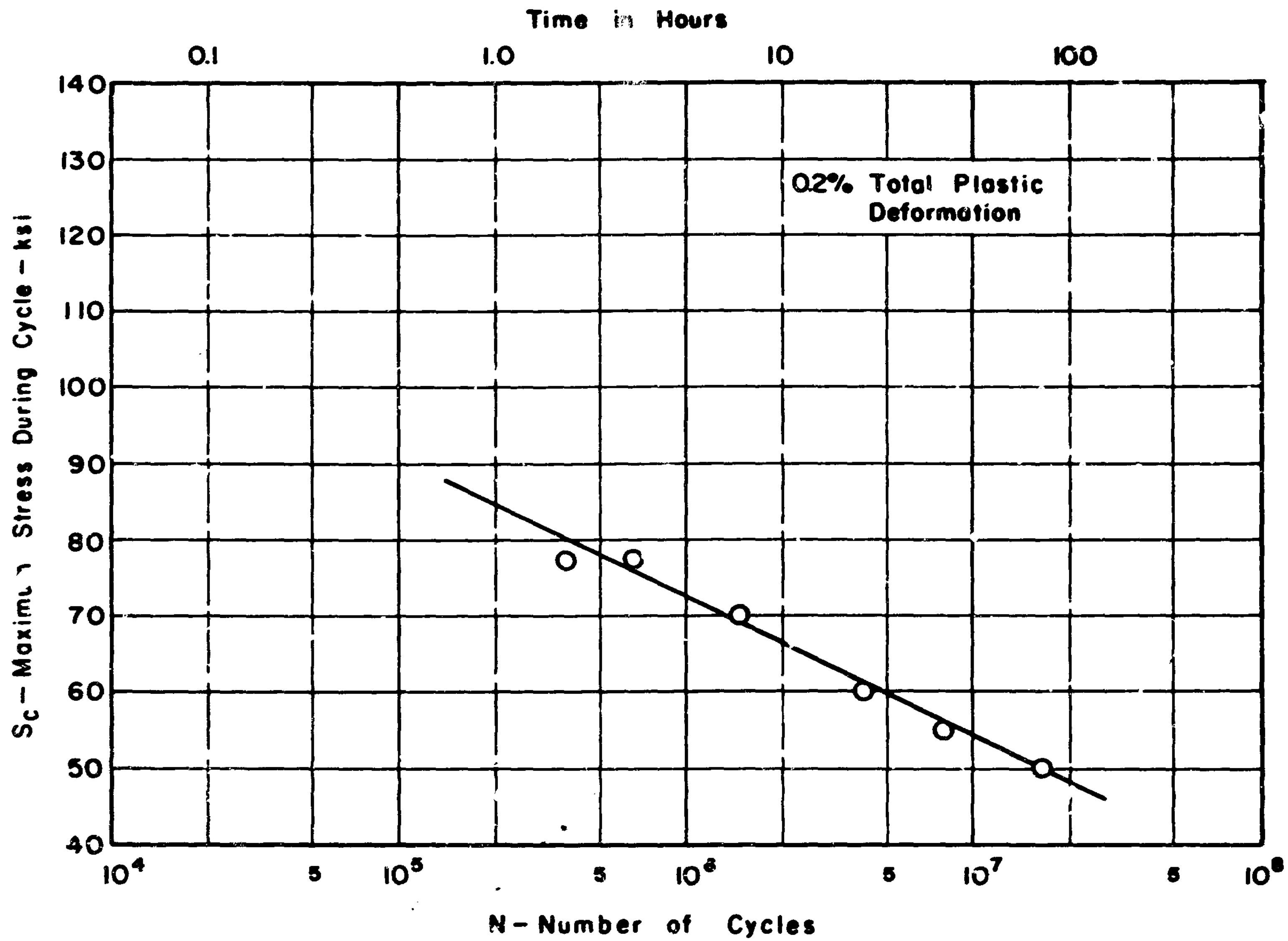


Figure 67 0.2% Total Plastic Deformation for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 0.67 and at 1250°F.

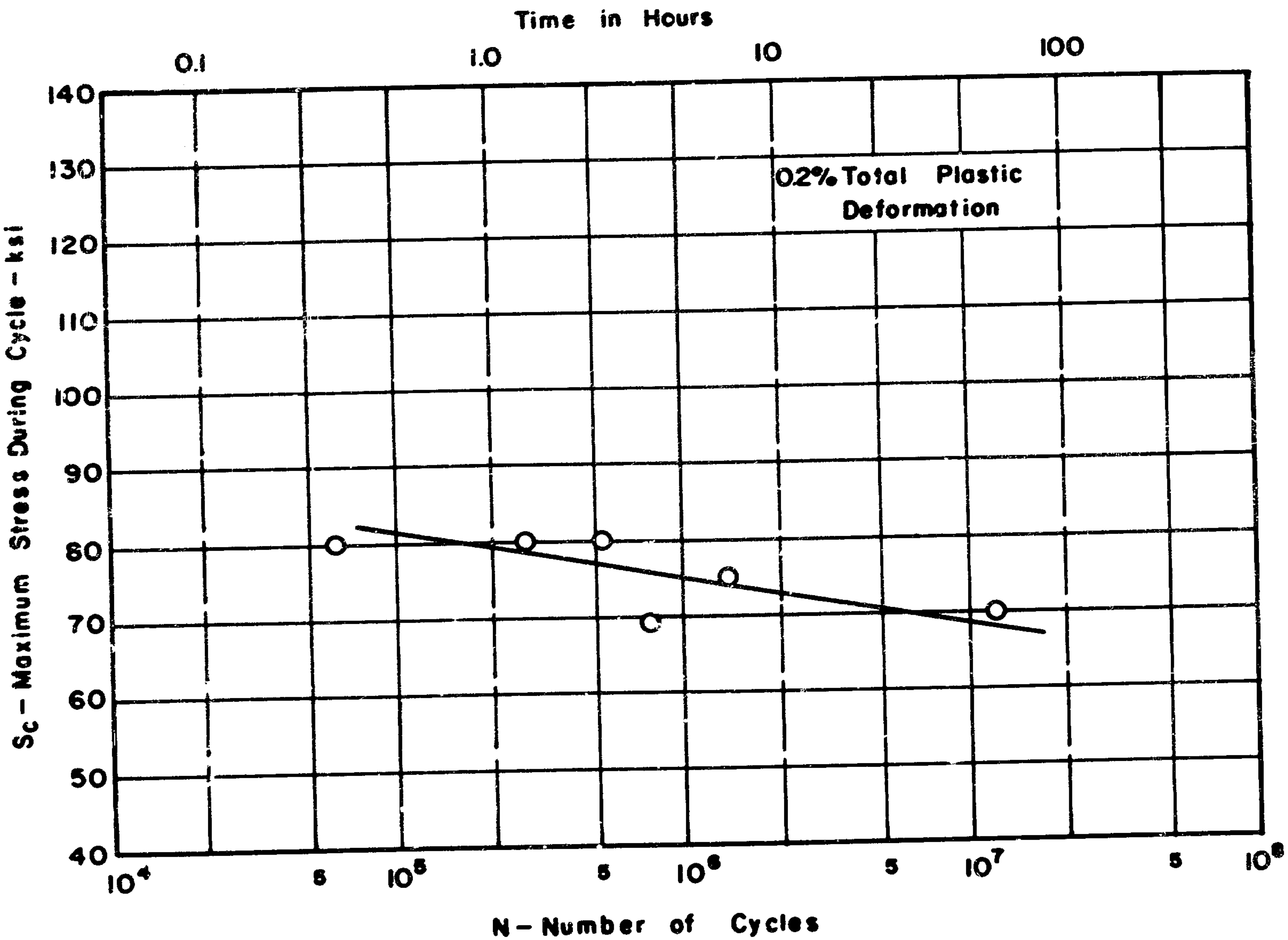


Figure 68 0.2% Total Plastic Deformation for Super A-286 at an Alternating-to-Mean Stress Ratio of A = 1.5 and at 1250°F.

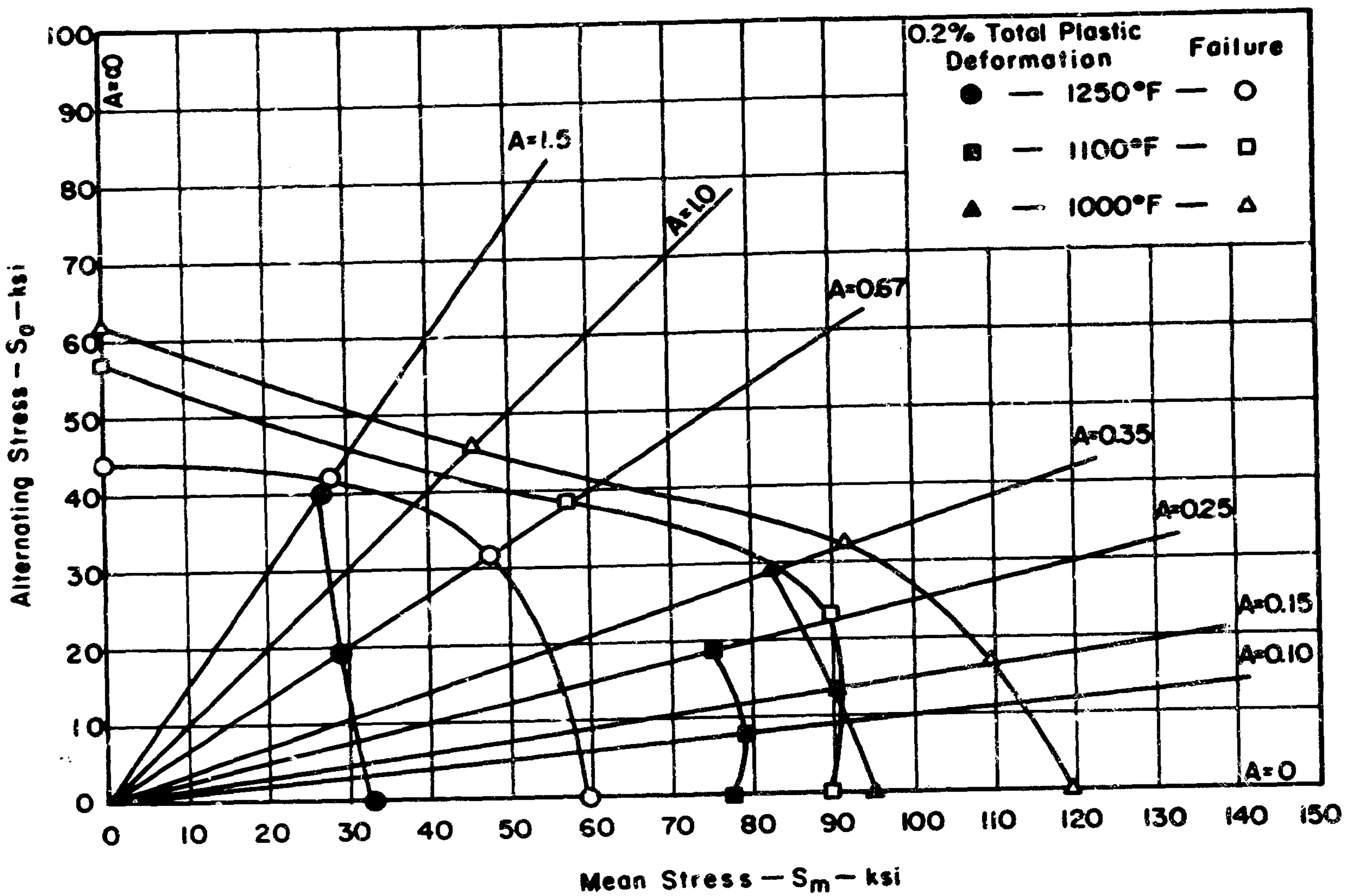


Figure 69 Combined 0.2% Total Plastic Deformation and Failure Stress Range Diagrams for Super A-286 at 1000°F, 1100°F, and 1250°F.

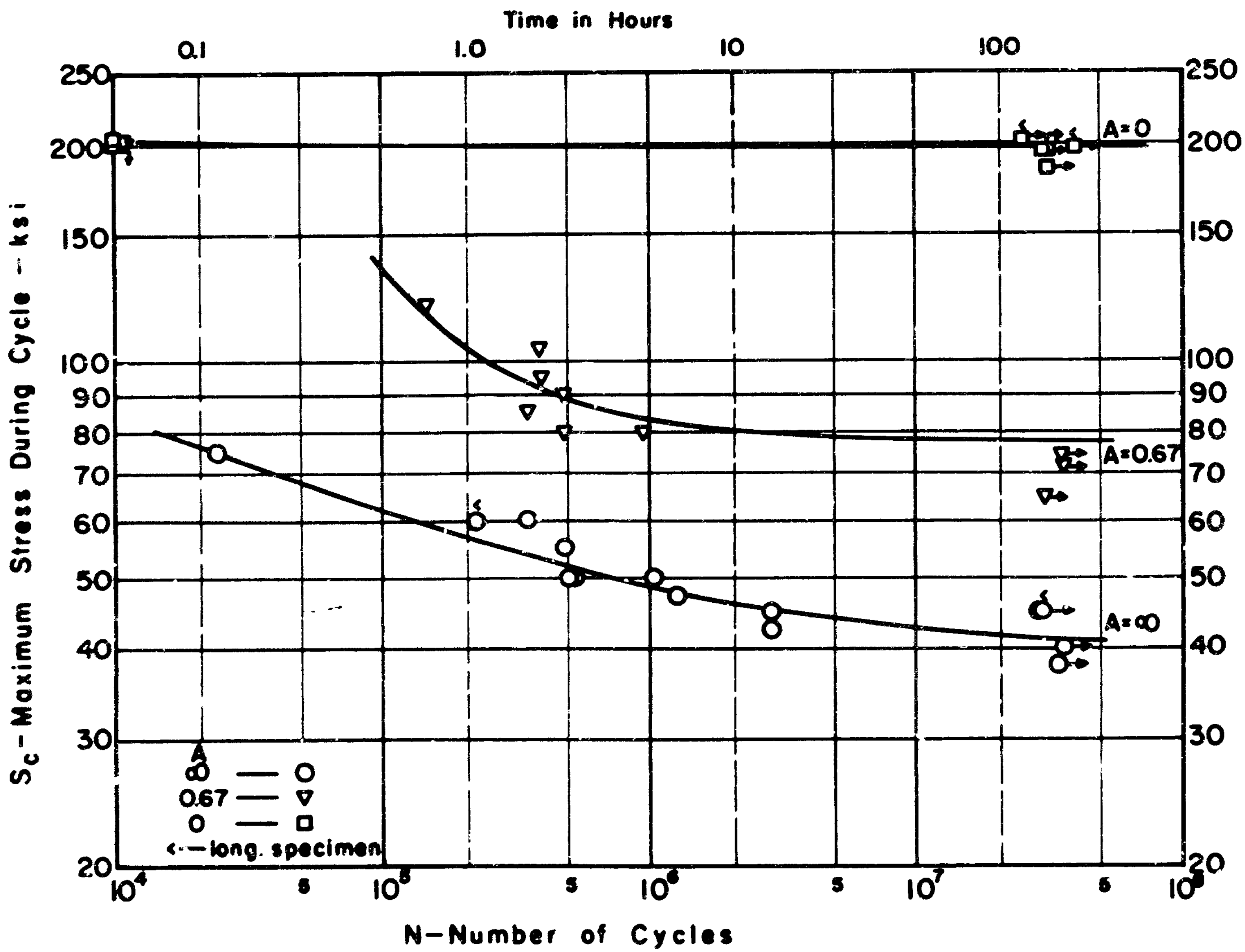


Figure 70 S-N Fatigue Diagram for Unnotched Transverse Inconel 718 Sheet at Various Alternating-to-Mean Stress Ratios and at 75°F.

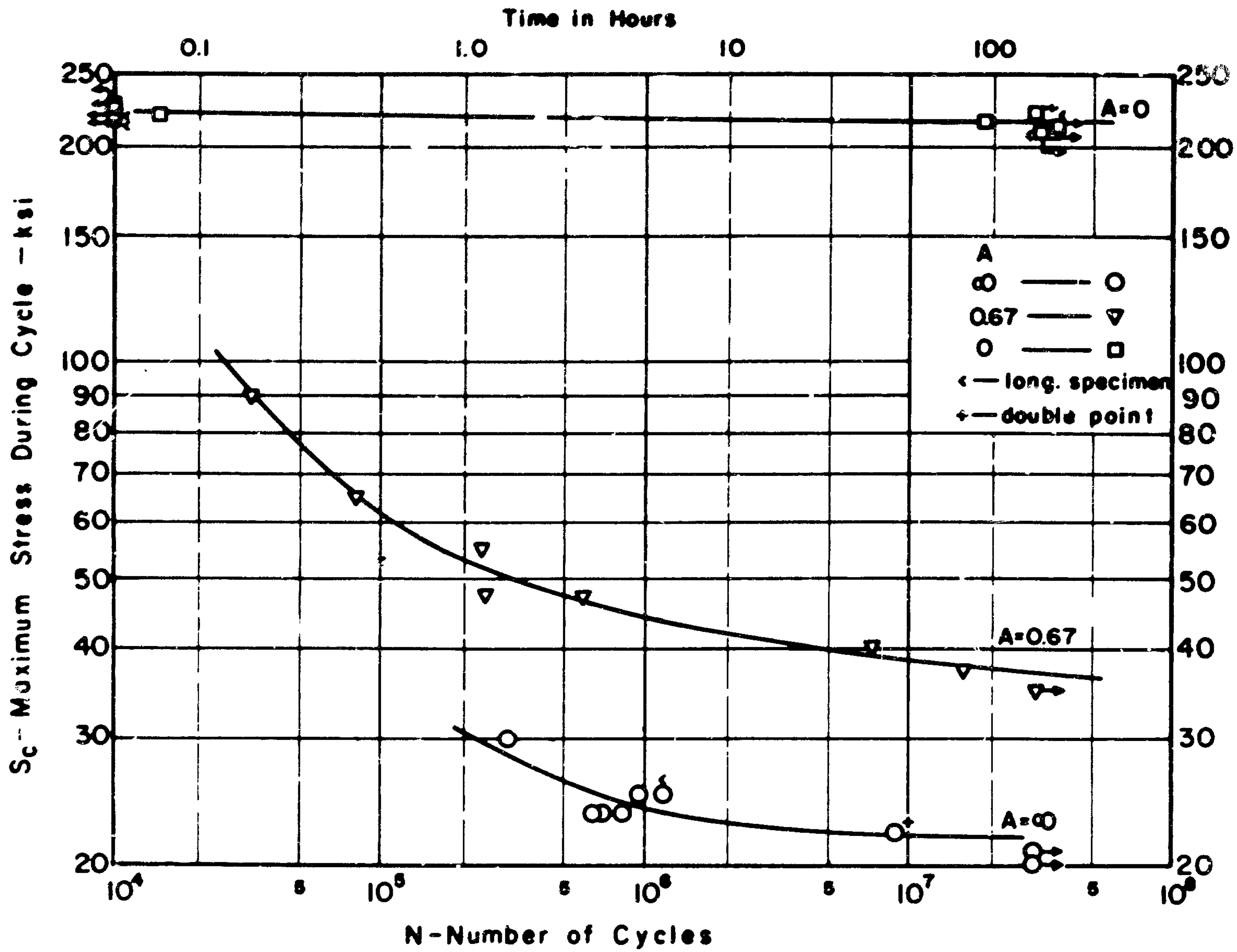


Figure 71 S-N Fatigue Diagram for Notched (K_t = 3.0) Transverse Inconel 718 Sheet at Various Alternating-to-Mean Stress Ratios and at 75°F.

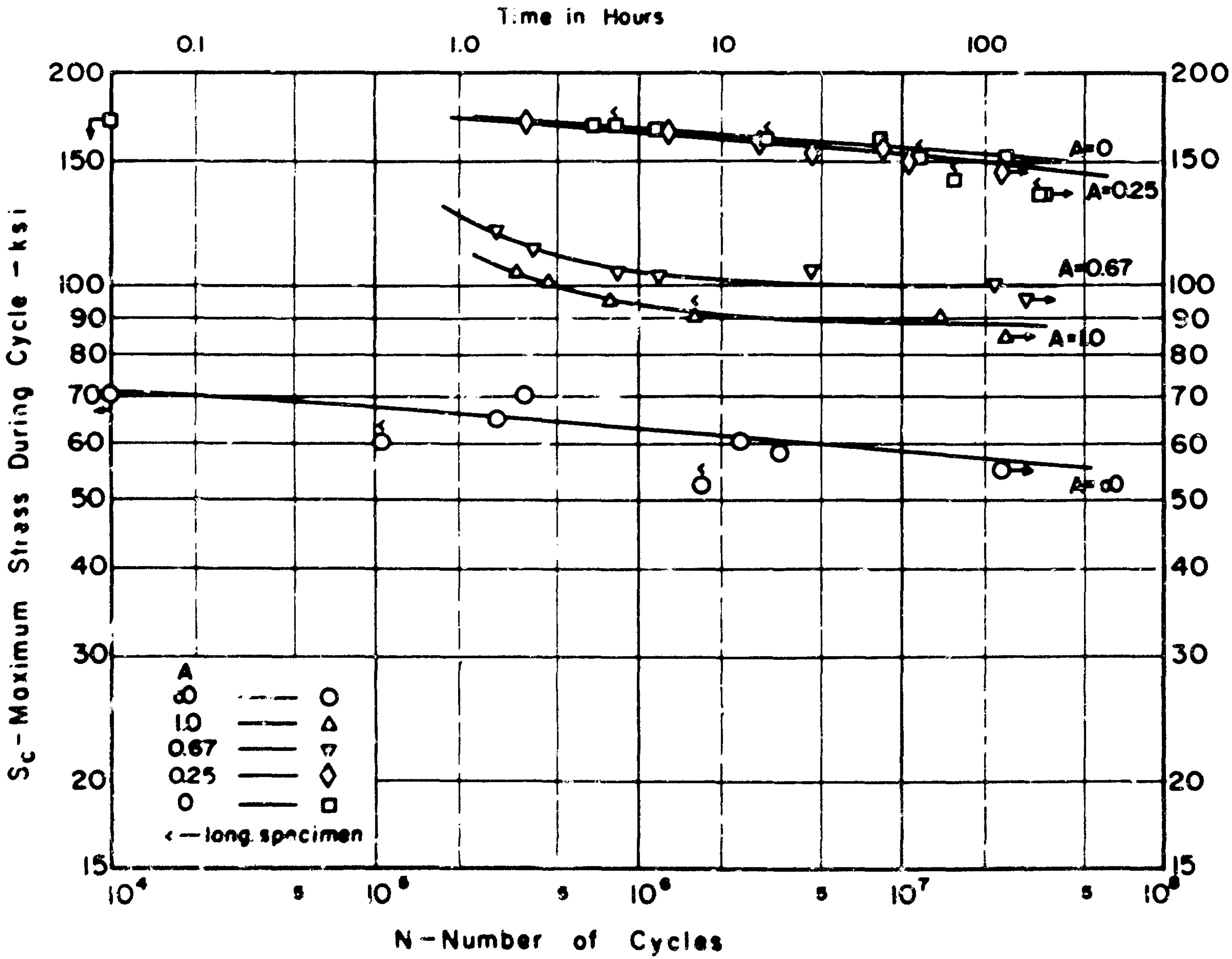


Figure 72 S-N Fatigue Diagram for Unnotched Inconel 718 Sheet at Various Alternating-to-Mean Stress Ratios and at 1000°F.

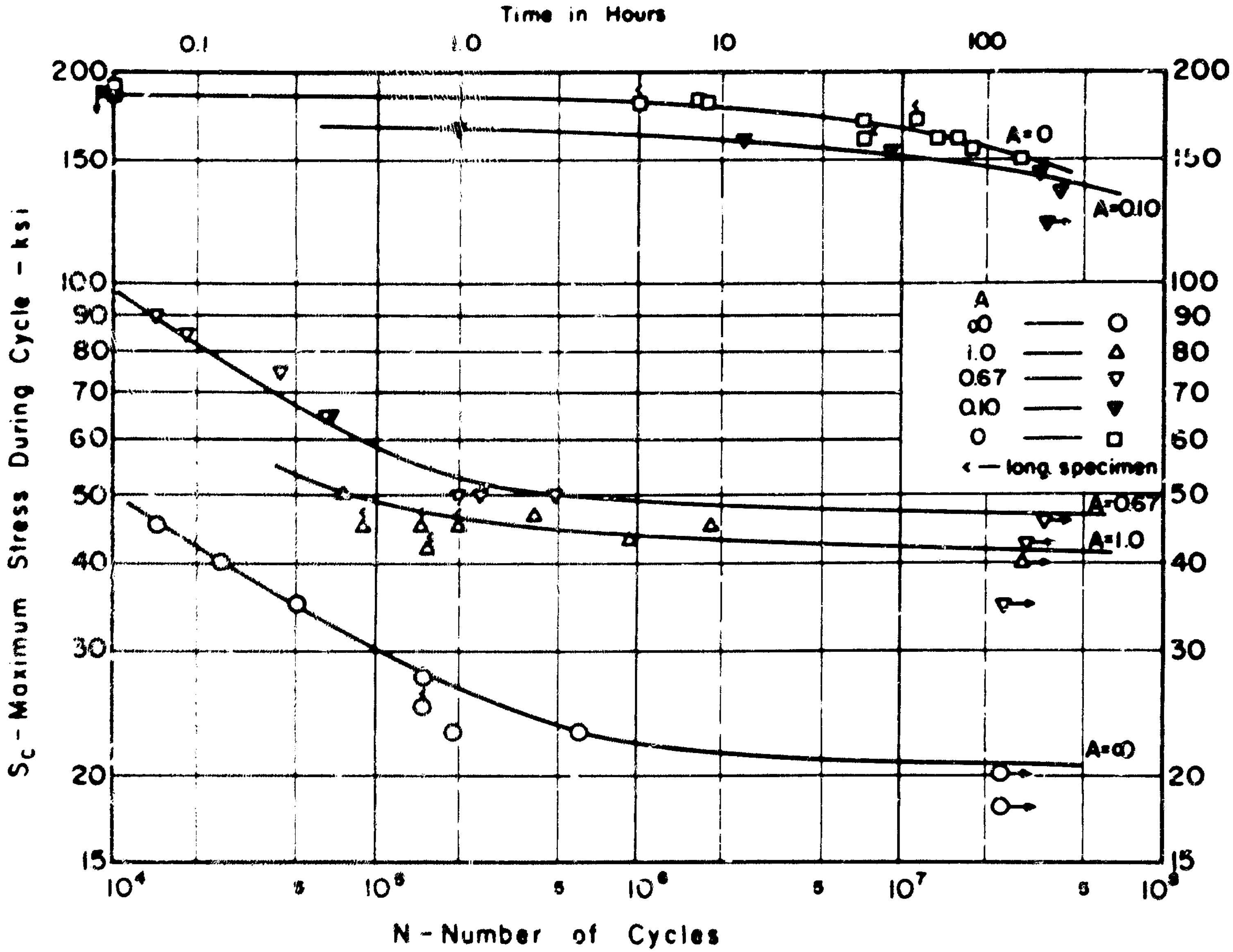


Figure 73 S-N Fatigue Diagram for Notched (K_t = 3.0) Transverse Inconel 718 Sheet at Various Alternating-to-Mean Stress Ratios and at 1000°F.

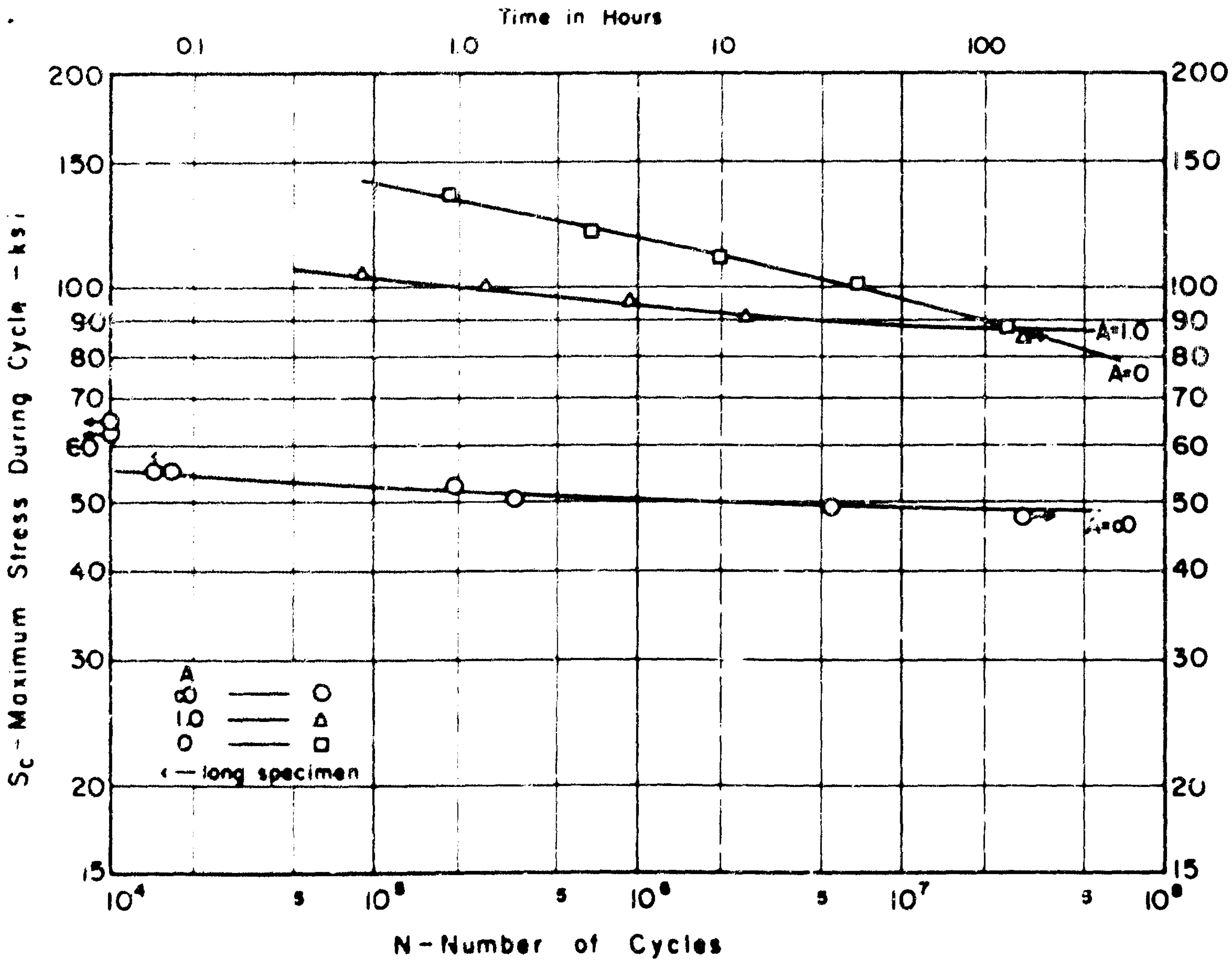


Figure 74 S-N Fatigue Diagram for Unnotched Transverse Inconel 718 Sheet at Various Alternating-to-Mean Stress Ratios and at 1200°F.

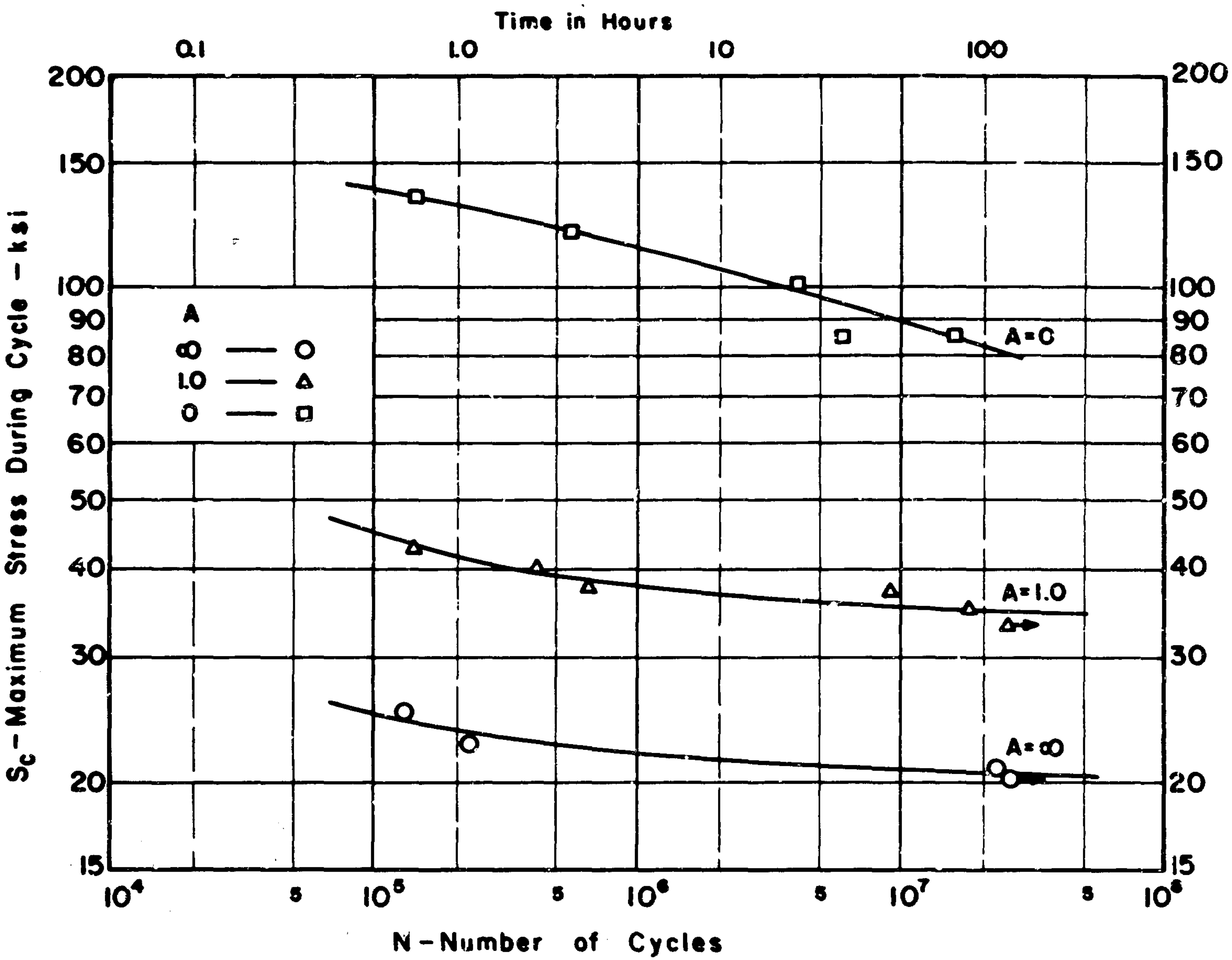


Figure 75 S-N Fatigue Diagram for Notched (K_t = 3.0) Transverse Inconel 718 Sheet at Various Alternating-to-Mean Stress Ratios and at 1200°F.

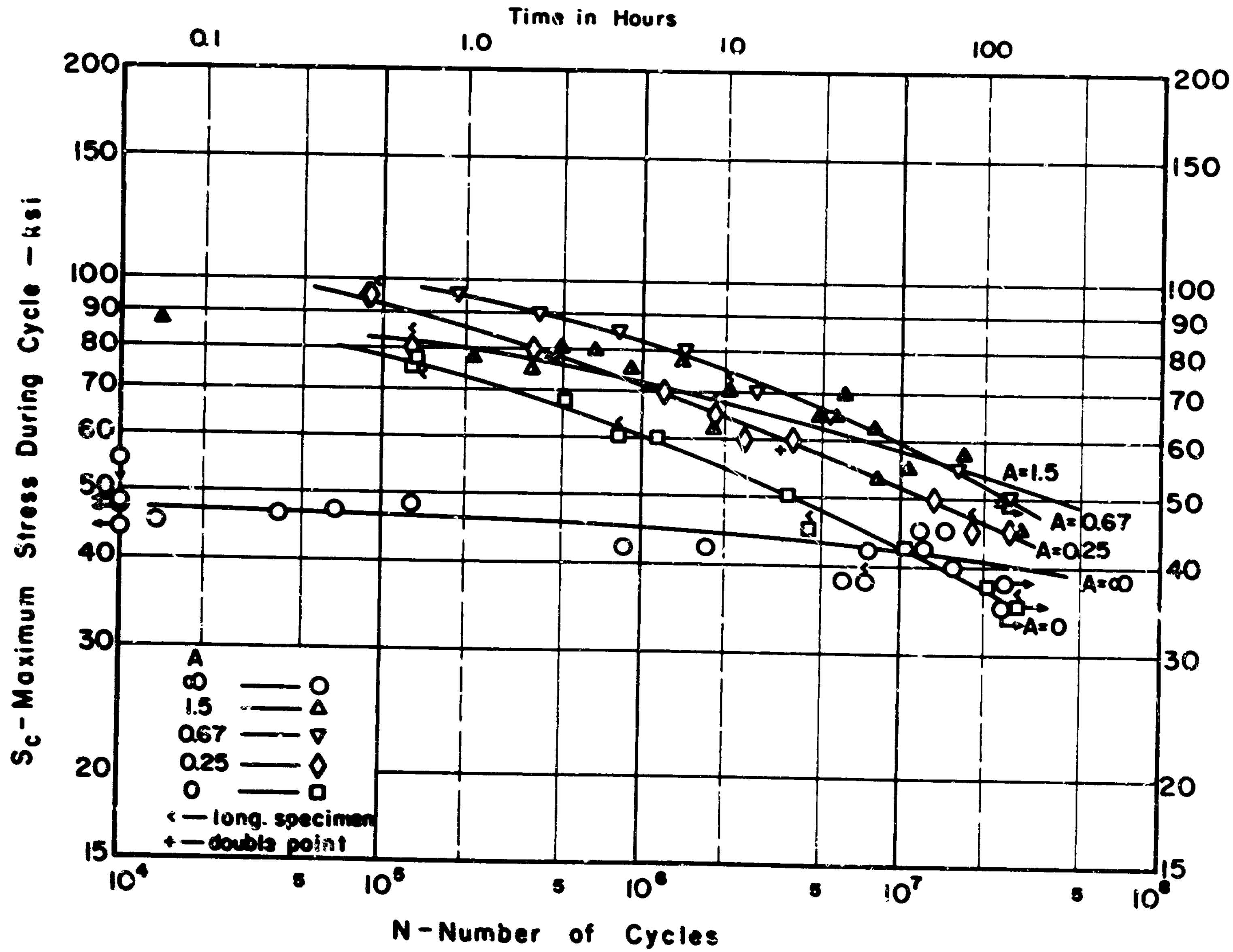


Figure 76 S-N Fatigue Diagram for Unnotched Transverse Inconel 718 Sheet at Various Alternating-to-Mean Stress Ratios and at 1400°F.

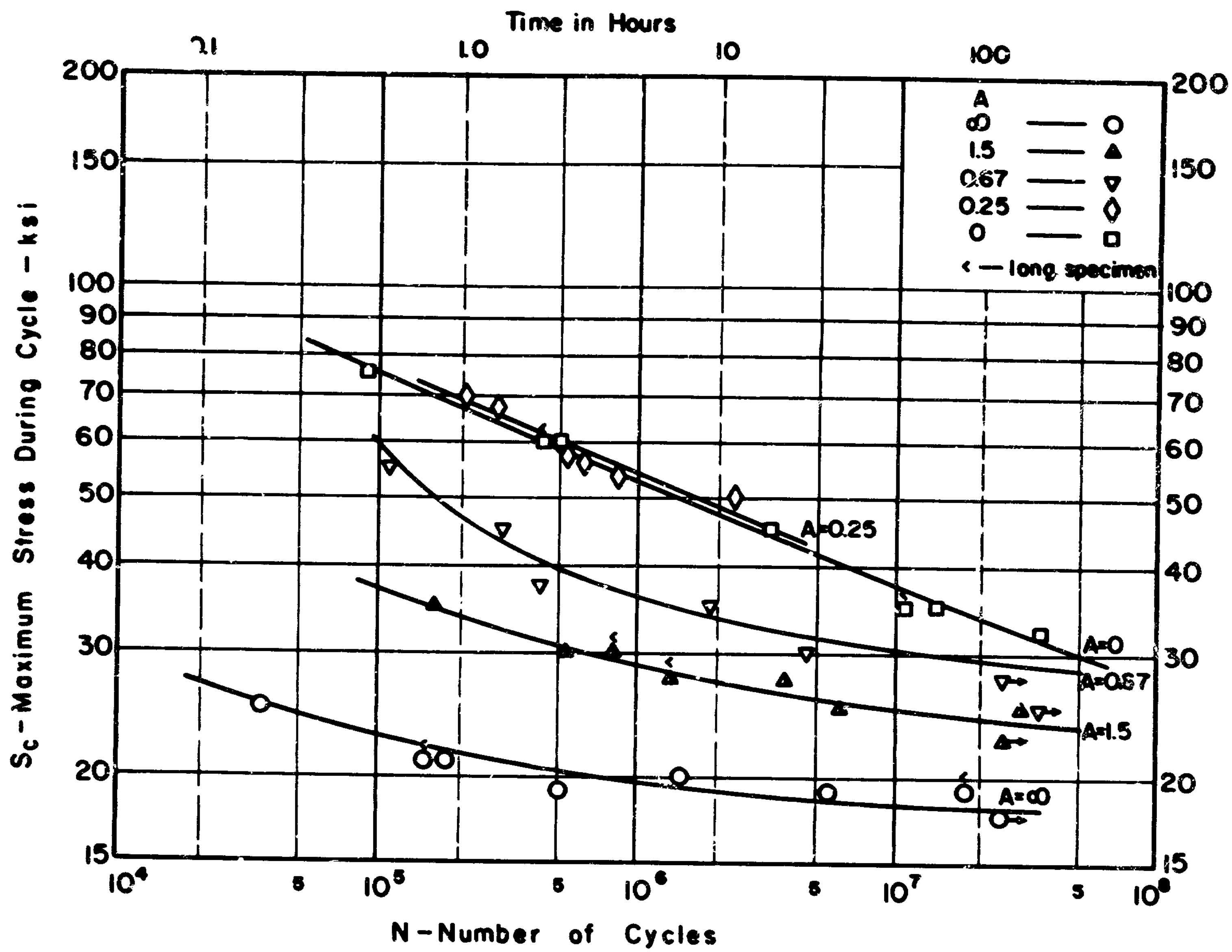


Figure 77 S-N Fatigue Diagram for Notched (K_t = 3.0) Transverse Inconel 718 Sheet at Various Alternating-to-Mean Stress Ratios and at 1400°F.

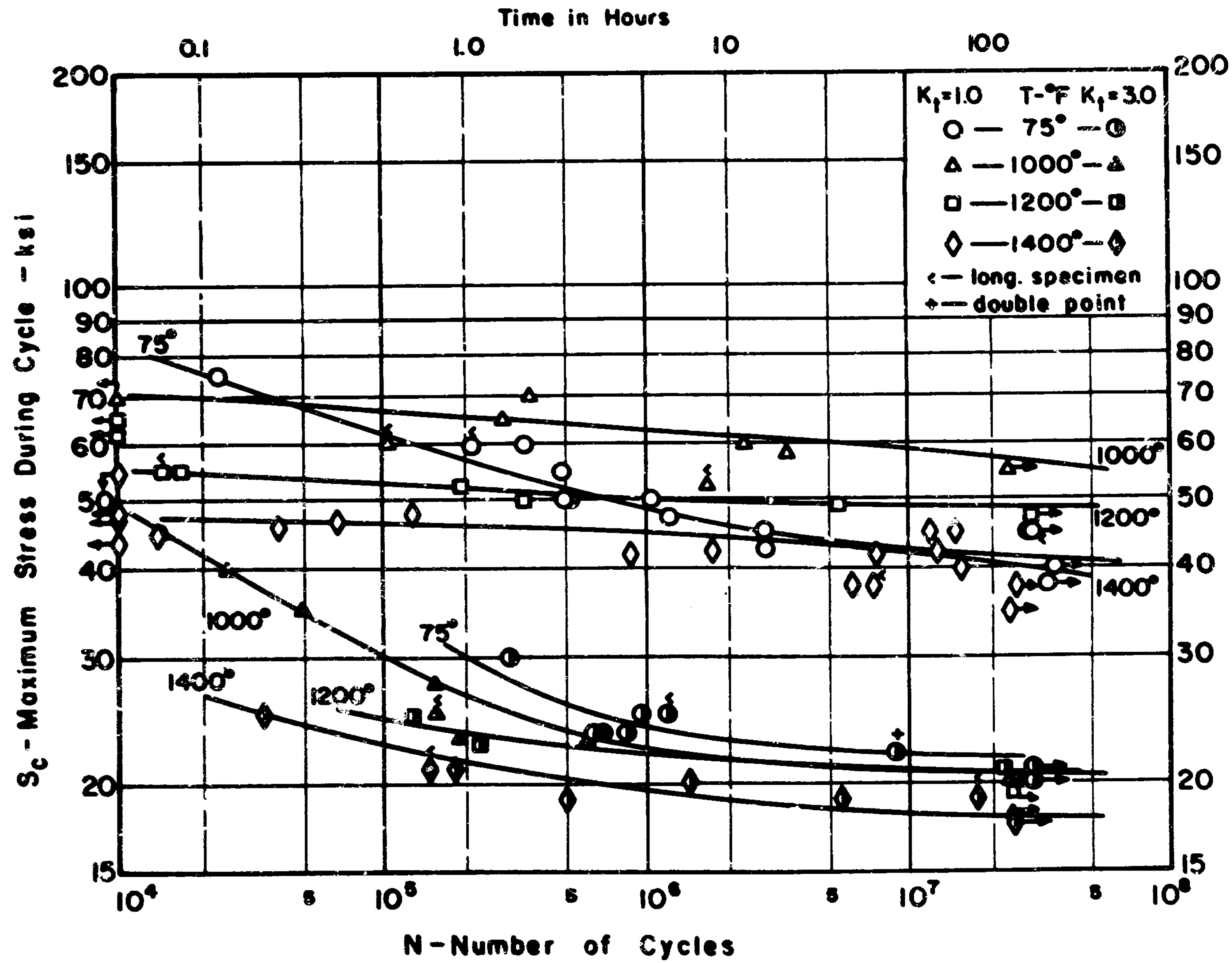


Figure 78 S-N Fatigue Diagram for Unnotched and Notched (K_t = 3.0) Transverse Inconel 718 Sheet Under Reversed Stress (A = ∞) and at 75°F, 1000°F, 1200°F, and 1400°F.

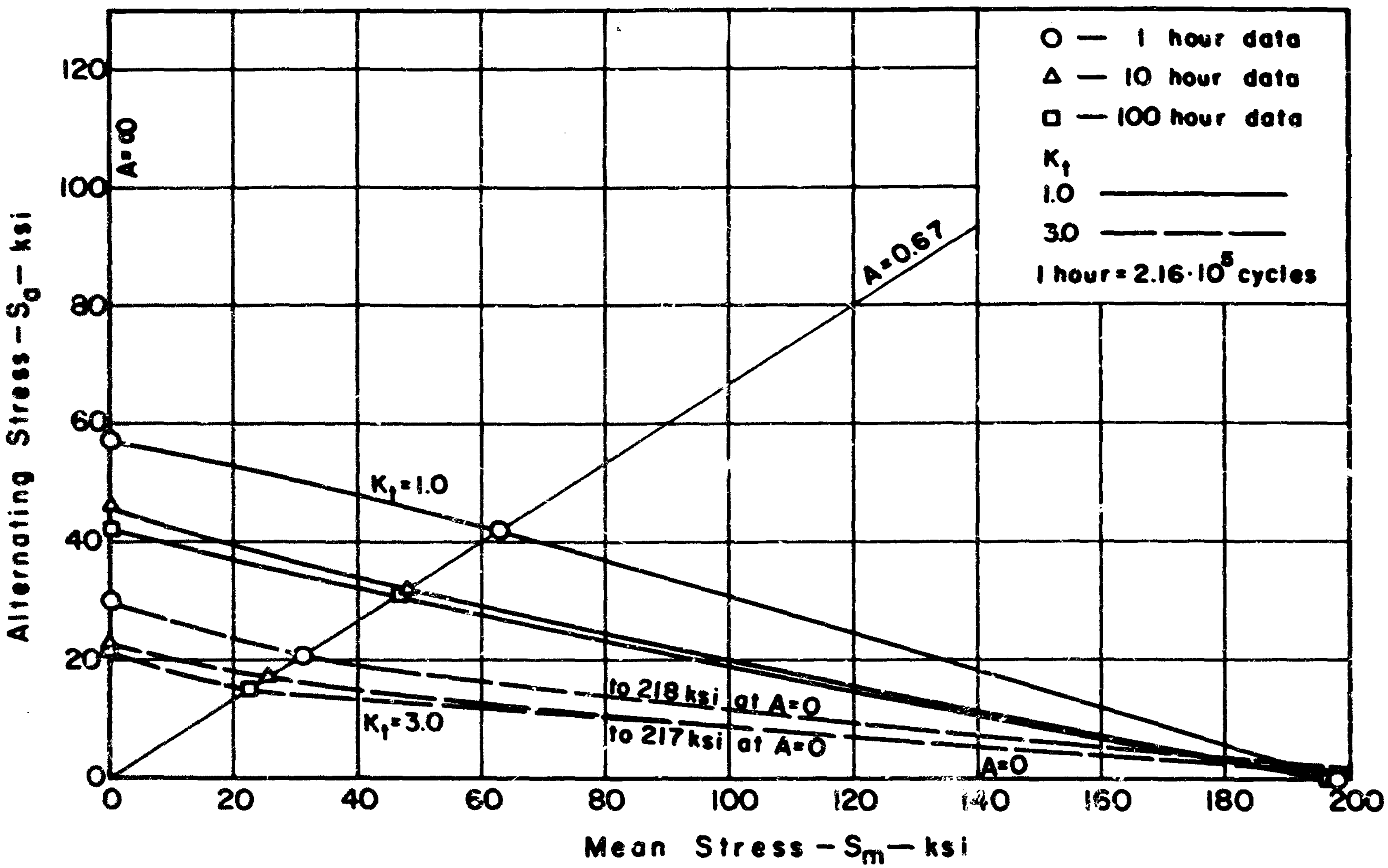


Figure 79 Stress Range Diagram for Unnotched and Notched Specimens of Transverse Inconel 718 Sheet at 75°F.

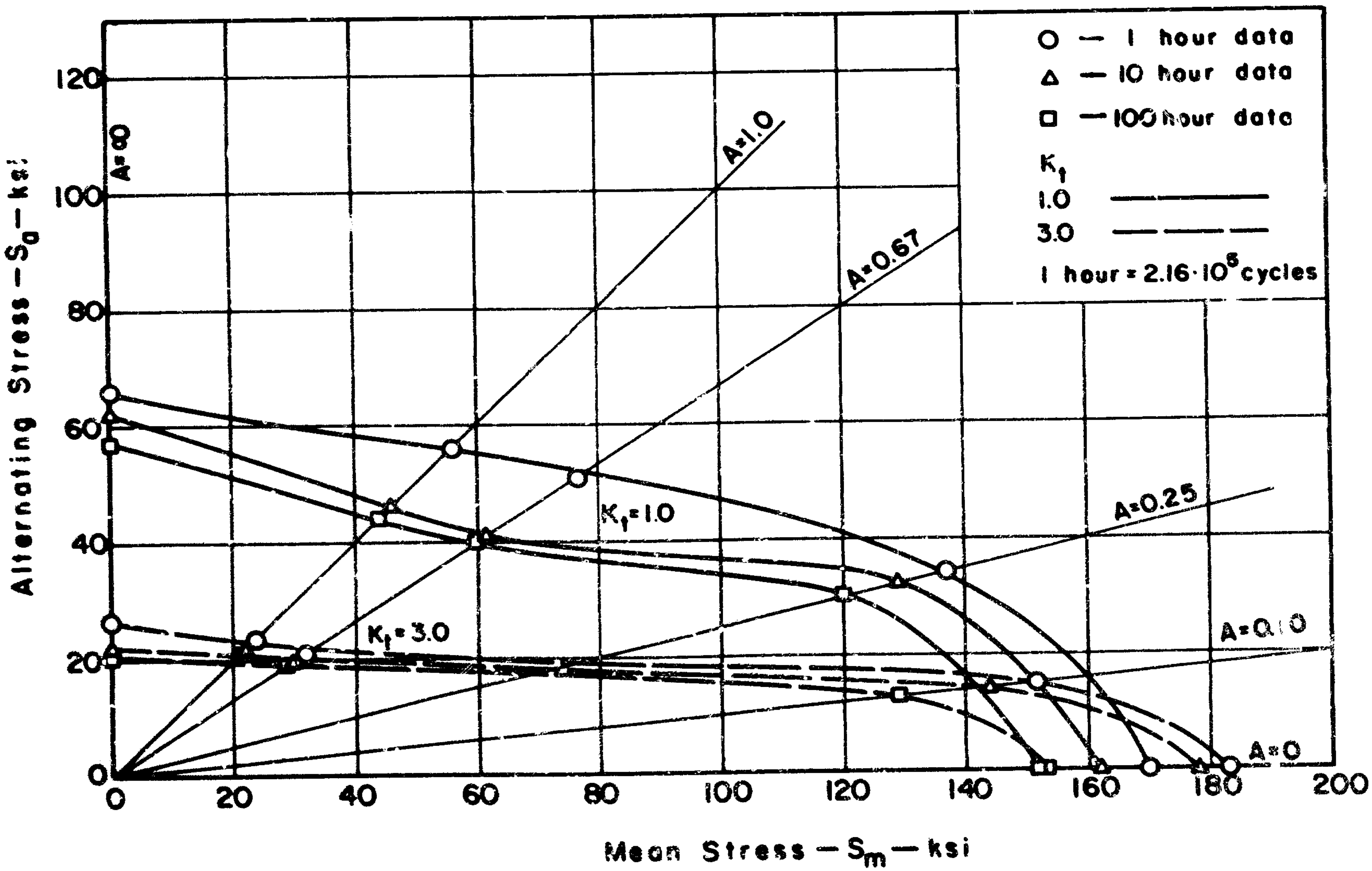


Figure 80 Stress Range Diagram for Unnotched and Notched Specimens of Transverse Inconel 718 Sheet at 1000°F.

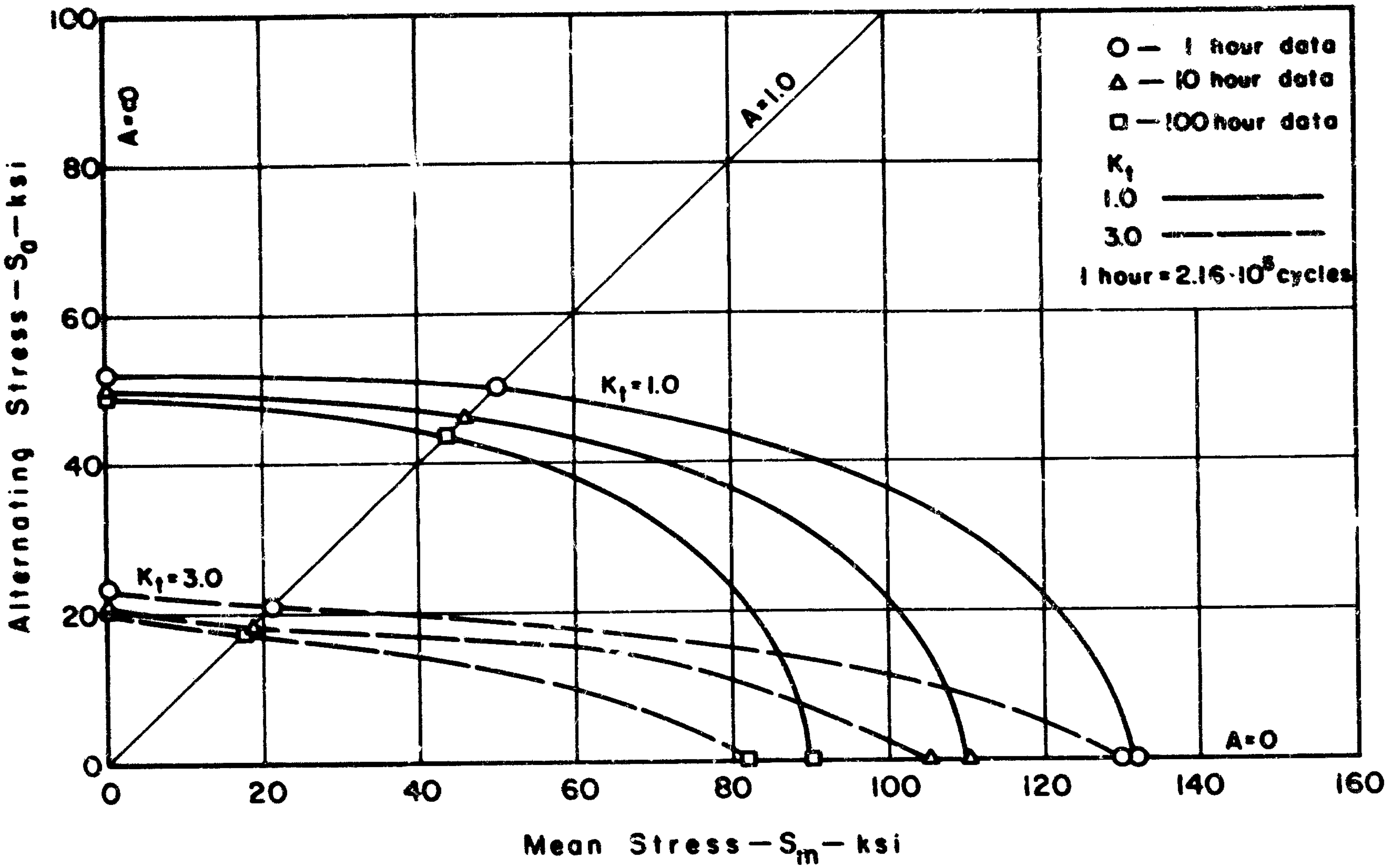


Figure 81 Stress Range Diagram for Unnotched and Notched Specimens of Transverse Inconel 718 Sheet at 1200°F.

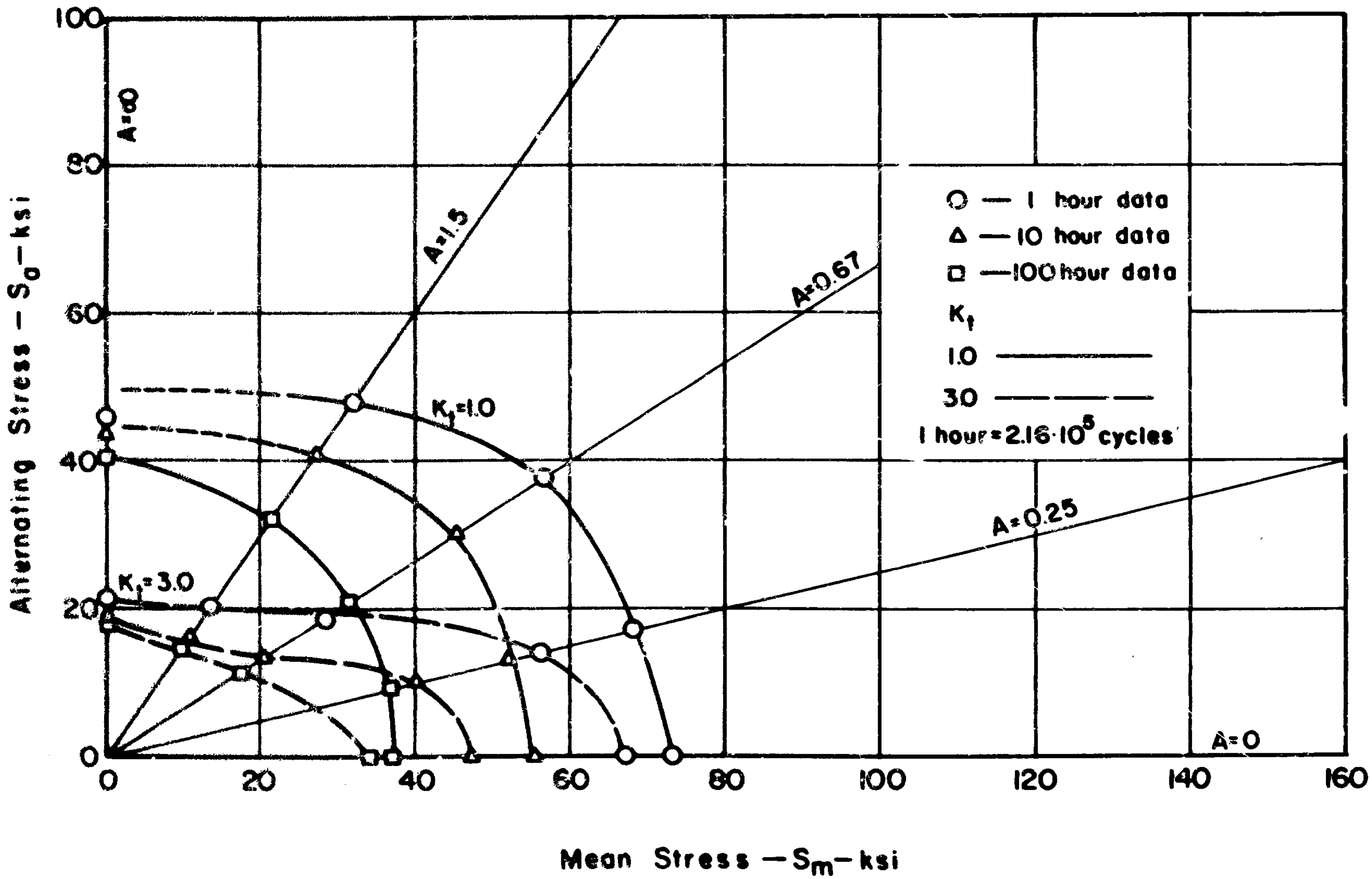


Figure 82 Stress Range Diagram for Unnotched and Notched Specimens of Transverse Inconel 718 Sheet at 1400°F.

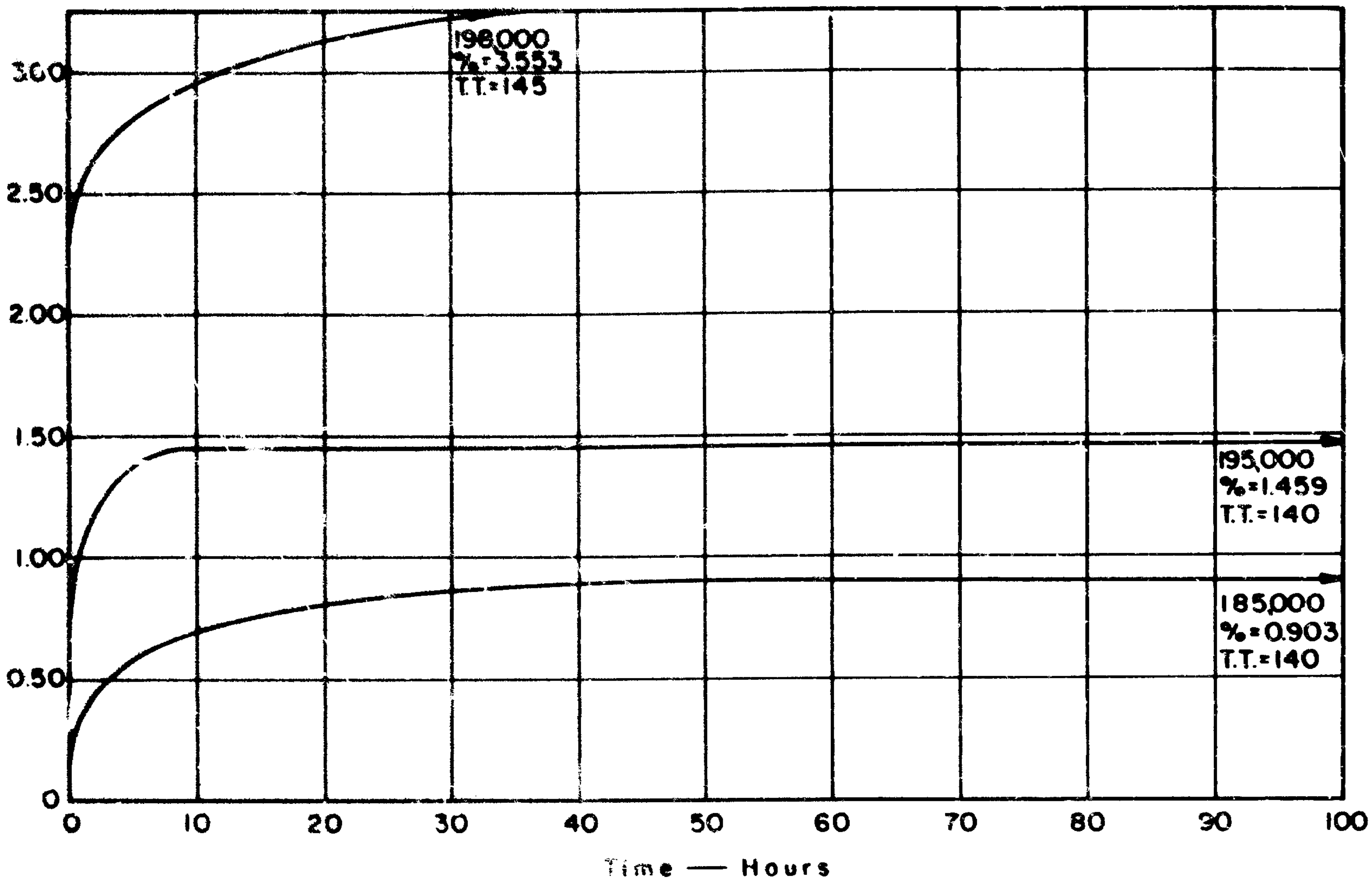


Figure 83 Creep Time Curves for Transverse Inconel 718 Sheet Under Static Load (A = 0) at 75°F.

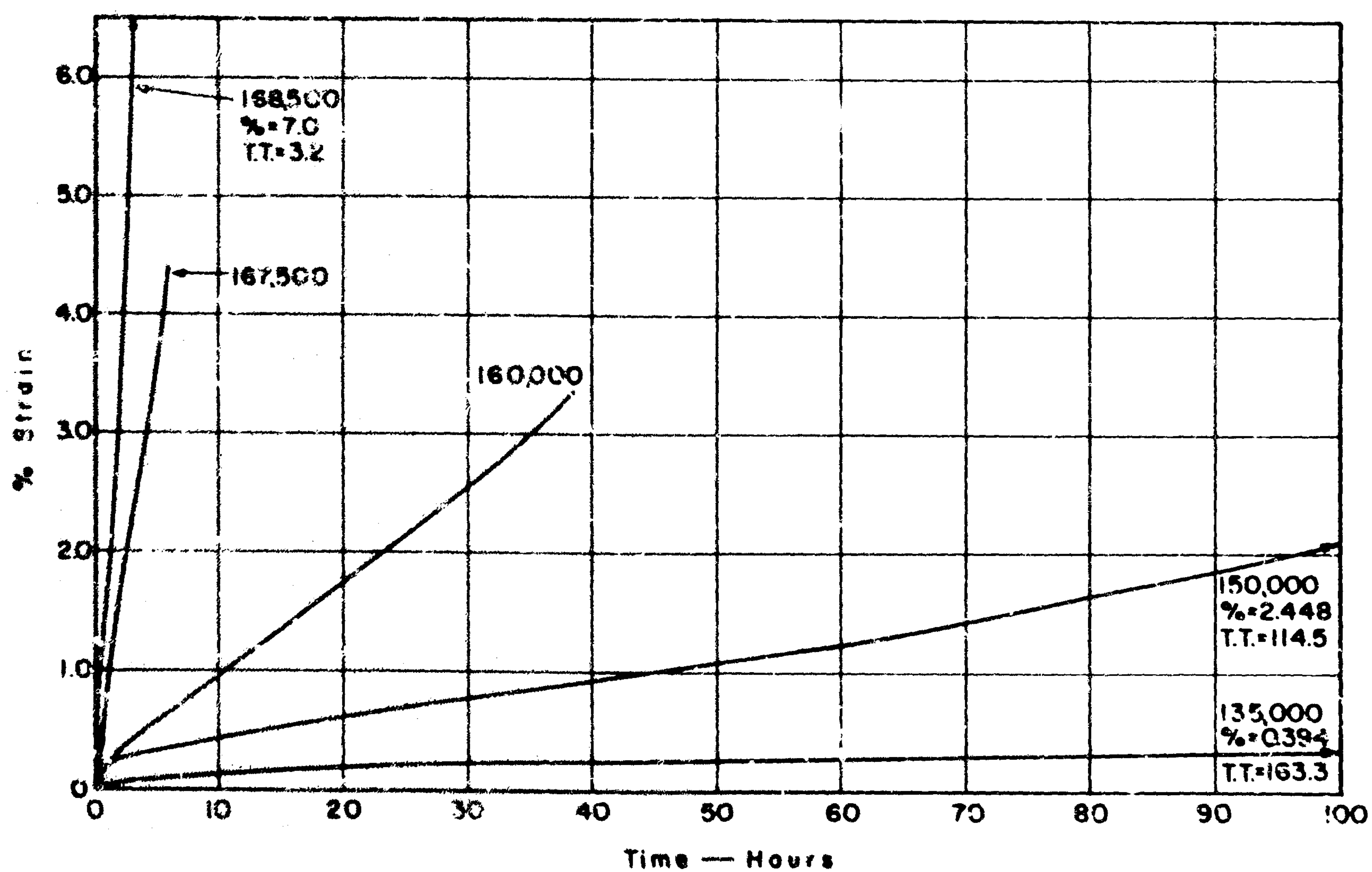


Figure 84 Creep Time Curves for Transverse Inconel 718 Sheet Under Static Load (A = 0) at 1000°F.

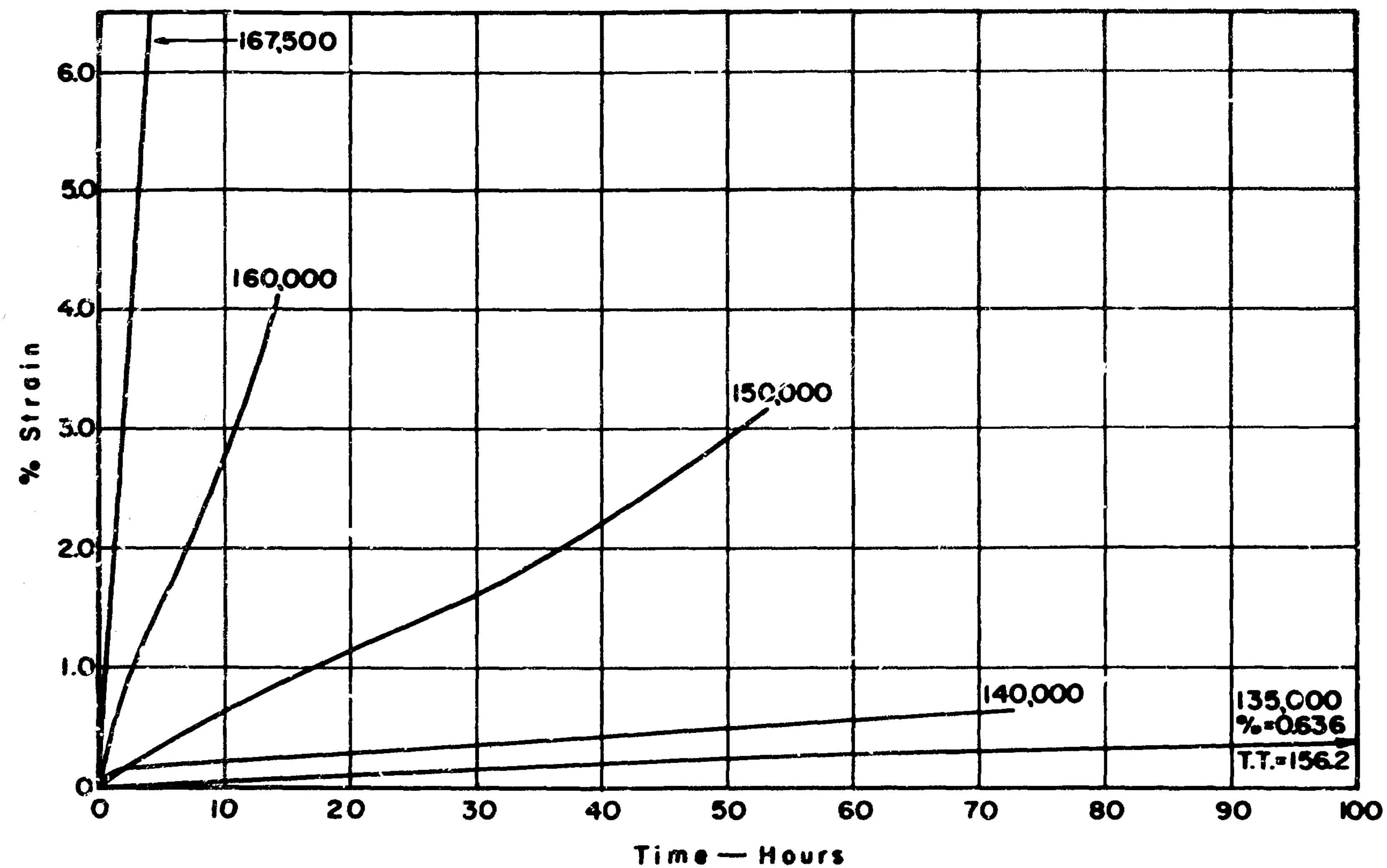


Figure 85 Creep Time Curves for Longitudinal Inconel 718 Sheet Under Static Load (A = 0) at 1000°F.

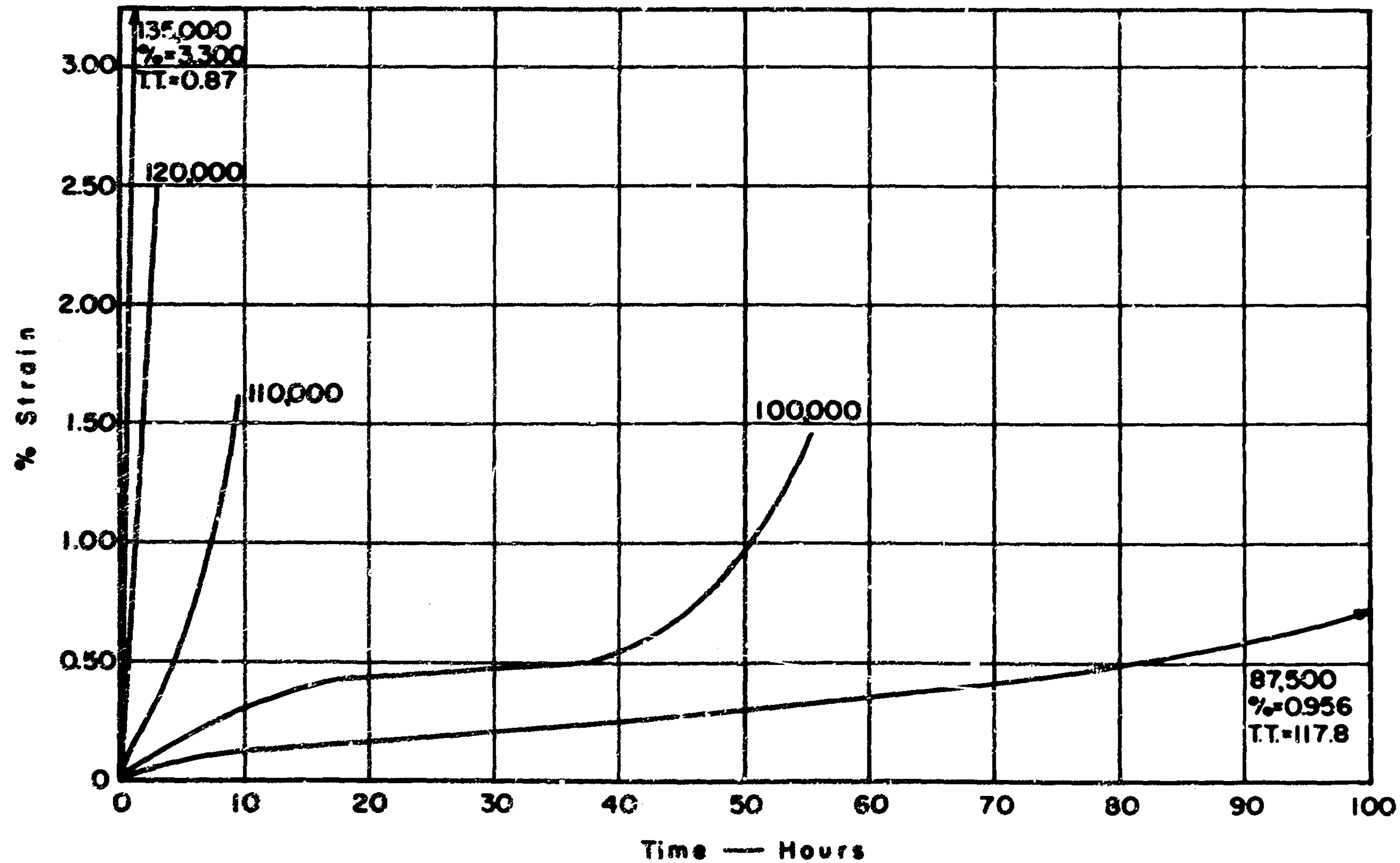


Figure 86 Creep Time Curves for Transverse Inconel 718 Sheet Under Static Load (A = 0) at 1200°F.

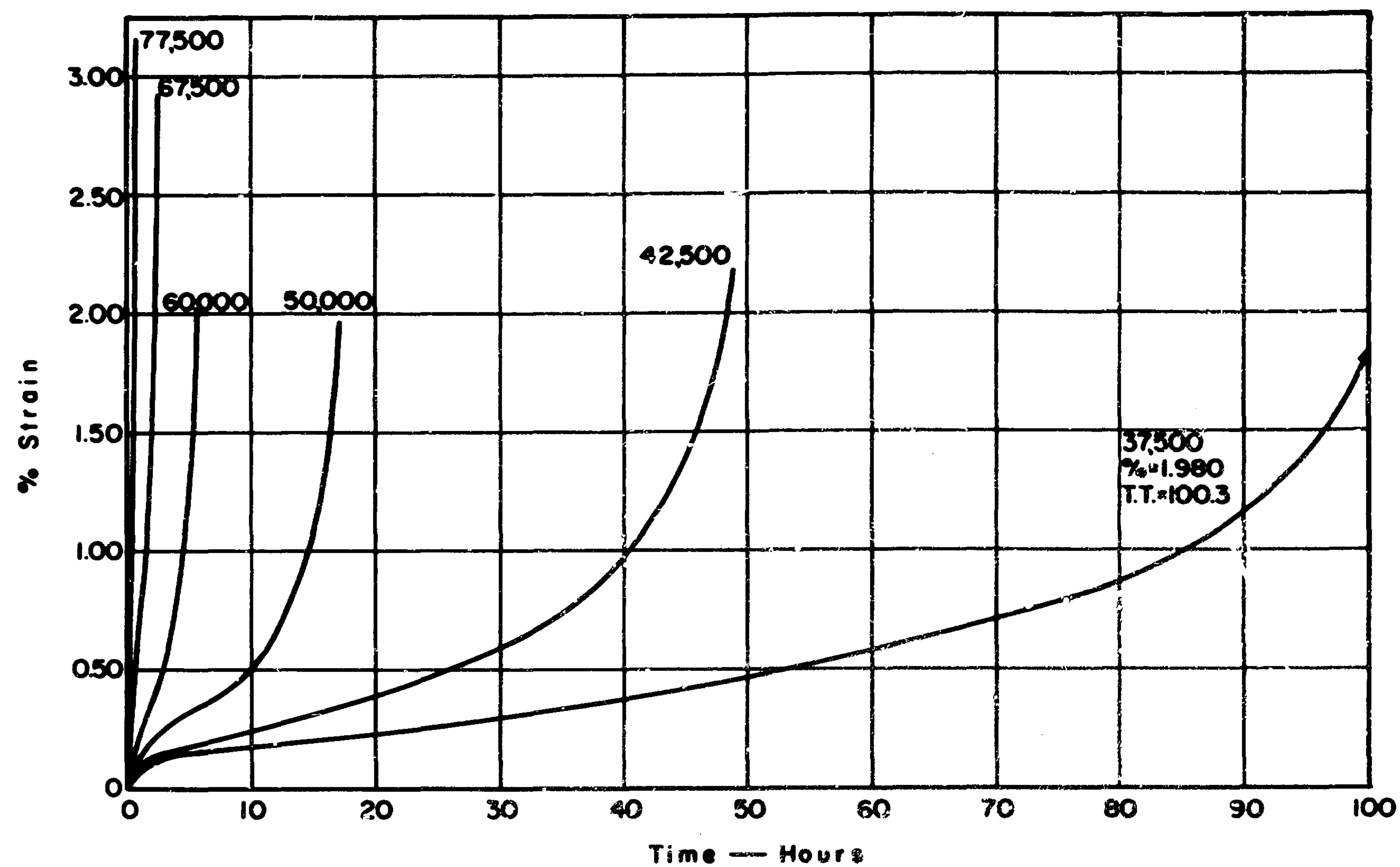


Figure 87 Creep Time Curves for Transverse Inconel 718 Sheet Under Static Load (A = 0) at 1400°F.

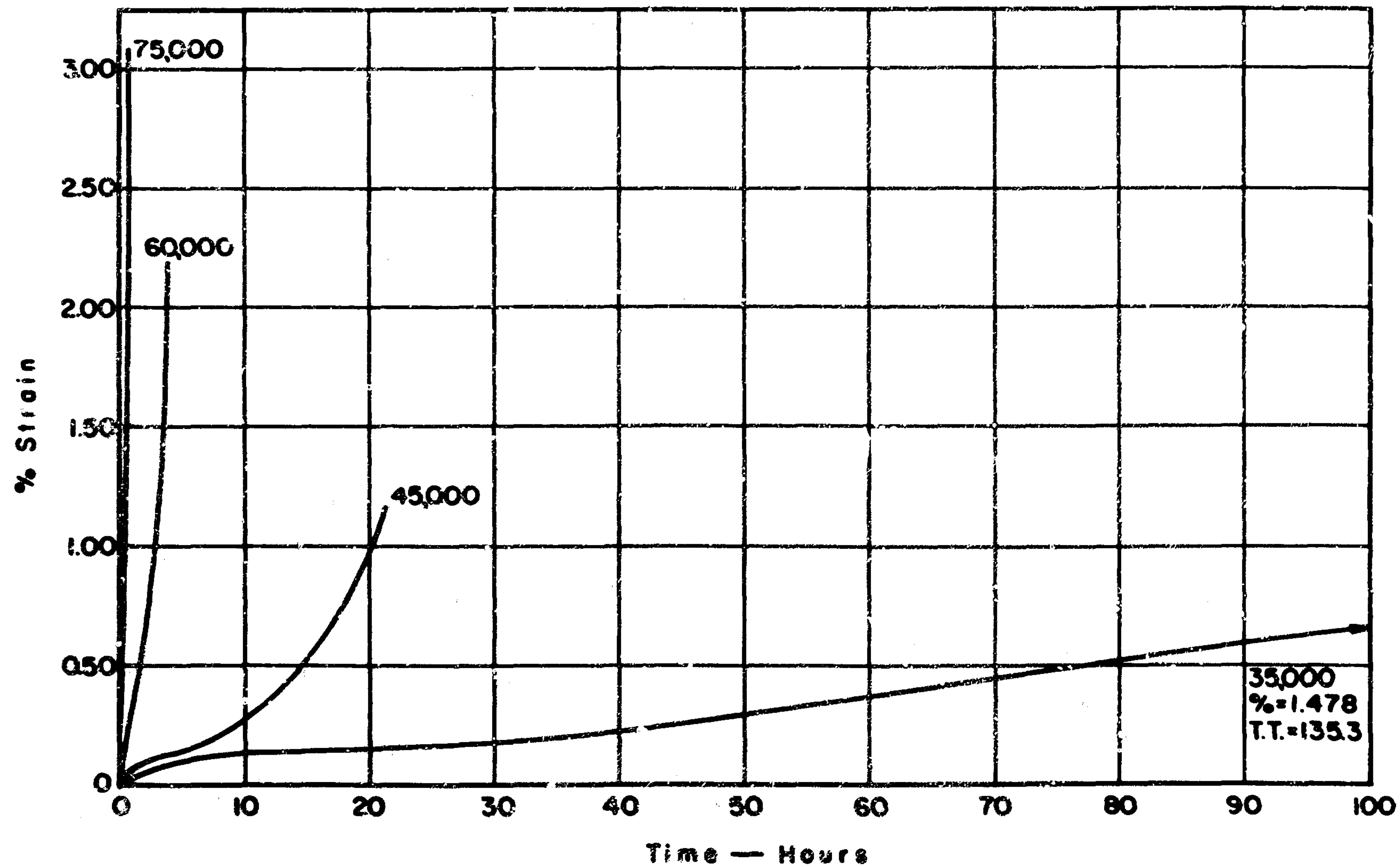


Figure 88 Creep Time Curves for Longitudinal Inconel 718 Sheet Under Static Load (A = 0) at 1400°F.

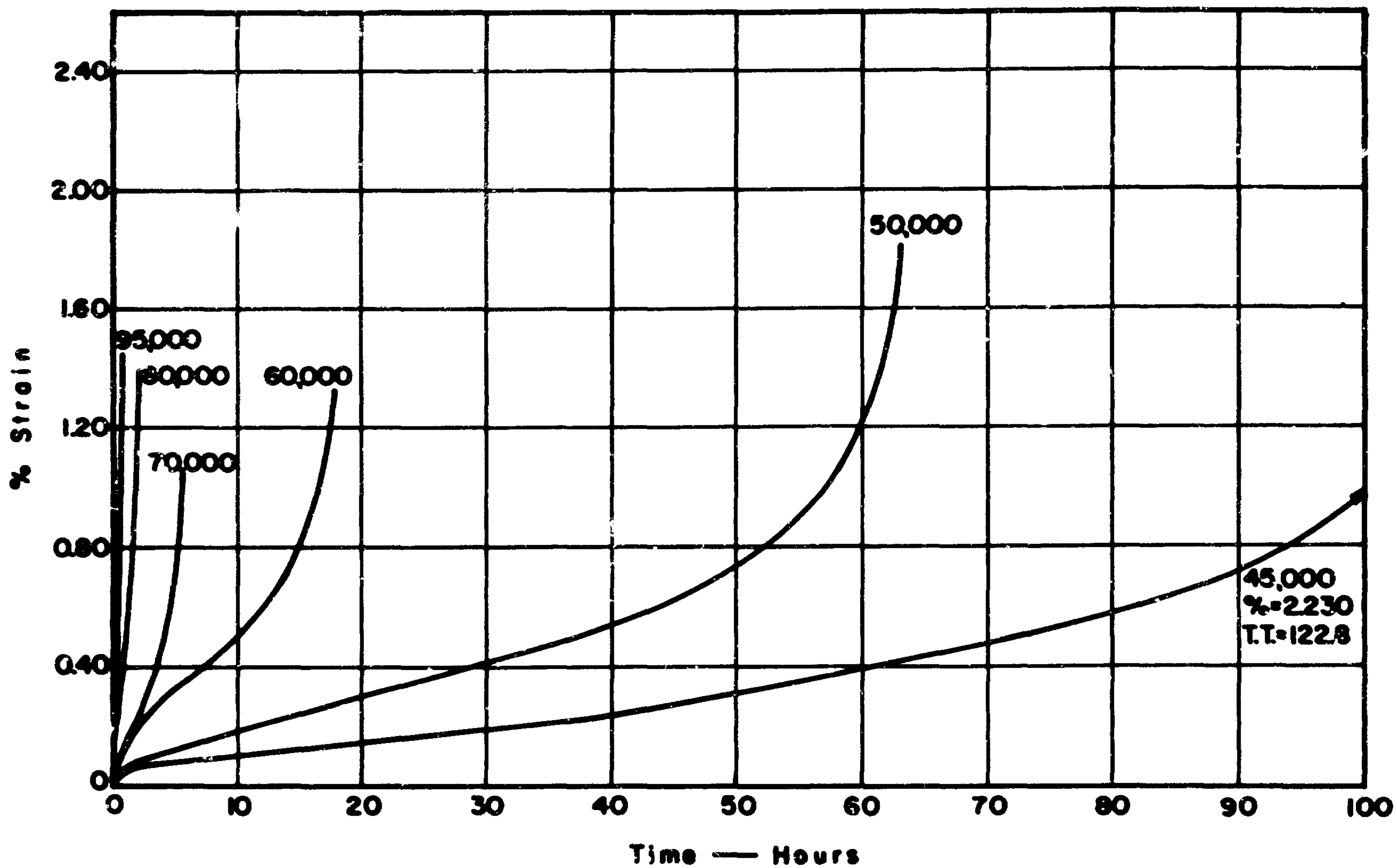


Figure 89 Creep Time Curves for Transverse Inconel 718 Sheet at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1400°F.

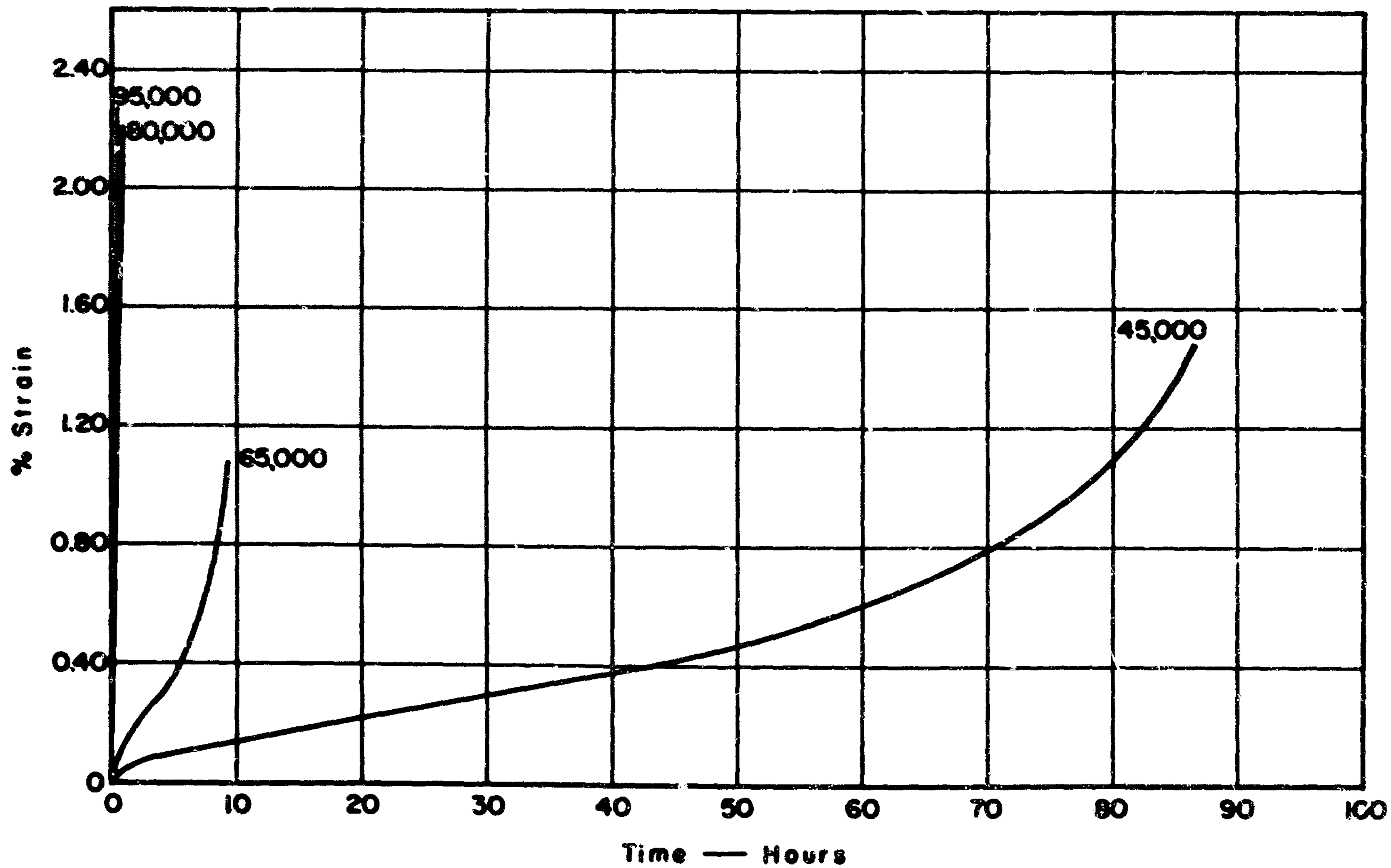


Figure 90 Creep Time Curves for Longitudinal Inconel 718 Sheet at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1400°F.

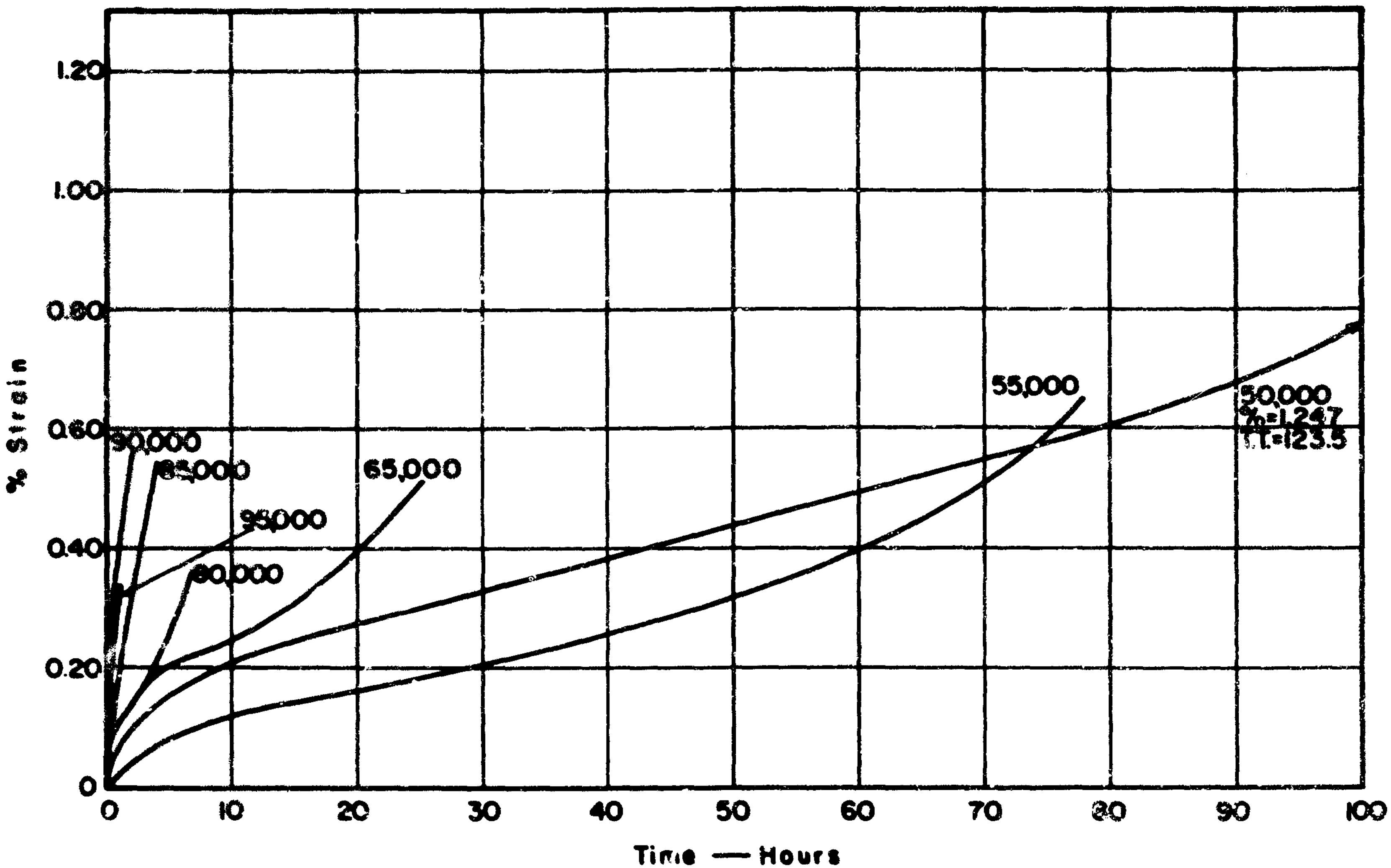


Figure 91 Creep Time Curves for Transverse Inconel 718 Sheet at an Alternating-to-Mean Stress Ratio of A = 0.67 and at 1400°F.

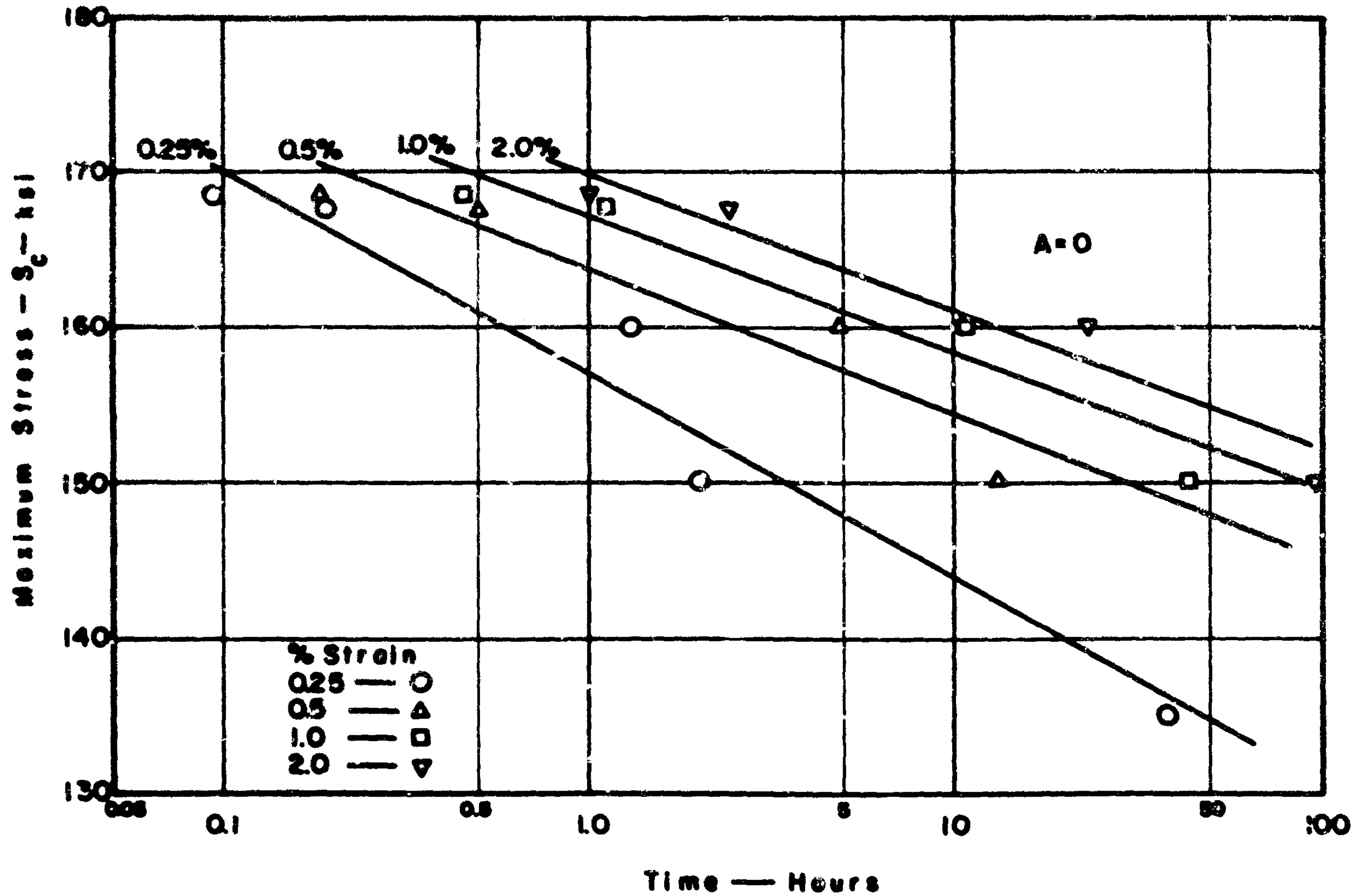


Figure 92 Maximum Stress Versus Time for Various Amounts of Creep for Transverse Inconel 718 Sheet Under Static Load (A = 0) at 1000°F.

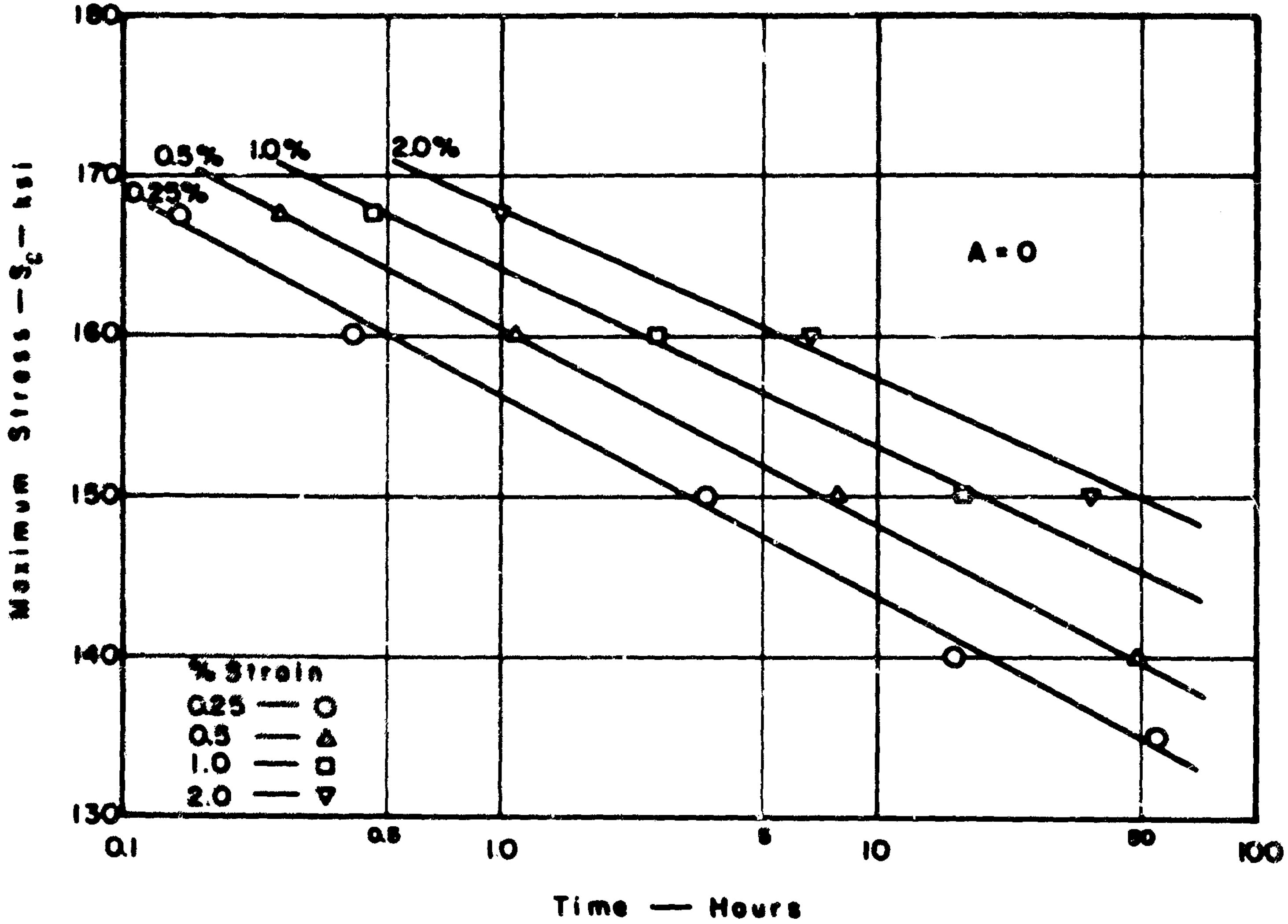


Figure 93 Maximum Stress Versus Time for Various Amounts of Creep for Longitudinal Inconel 718 Sheet Under Static Load (A = 0) at 1000°F.

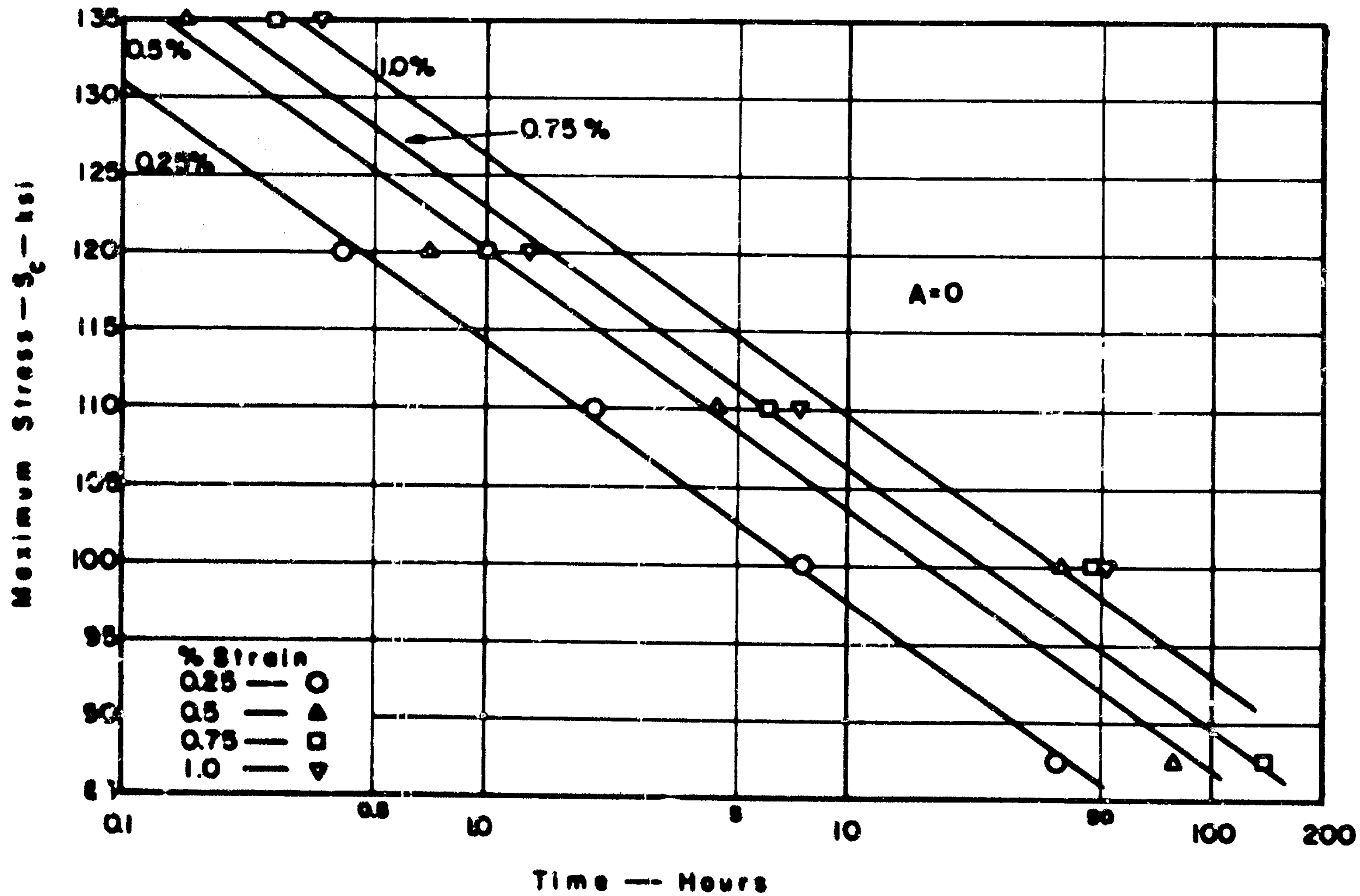


Figure 94 Maximum Stress Versus Time for Various Amounts of Creep for Transverse Inconel 718 Sheet Under Static Load (A = 0) at 1200°F.

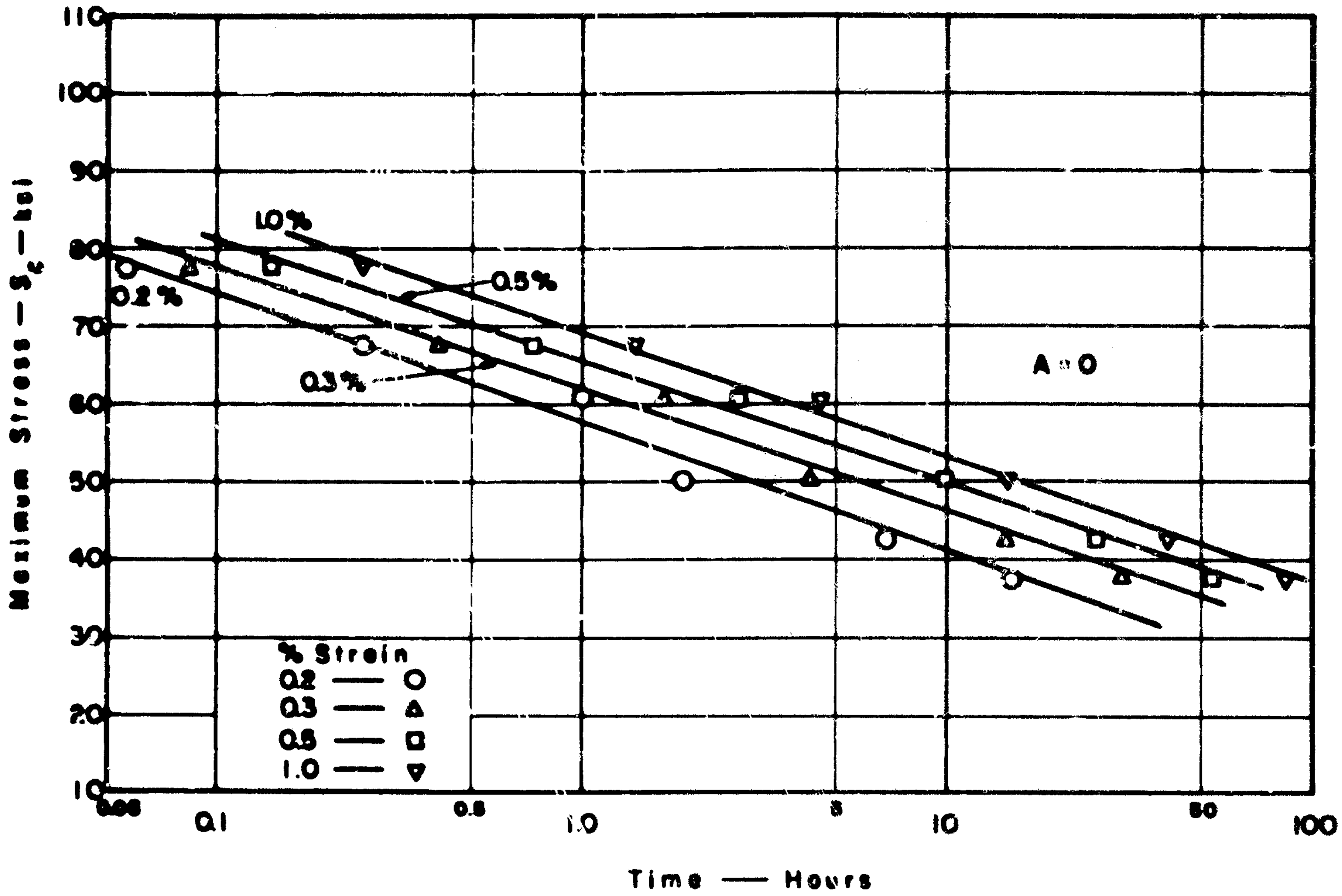


Figure 95 Maximum Stress Versus Time for Various Amounts of Creep for Transverse Inconel 718 Sheet Under Static Load (A = 0) at 1400°F.

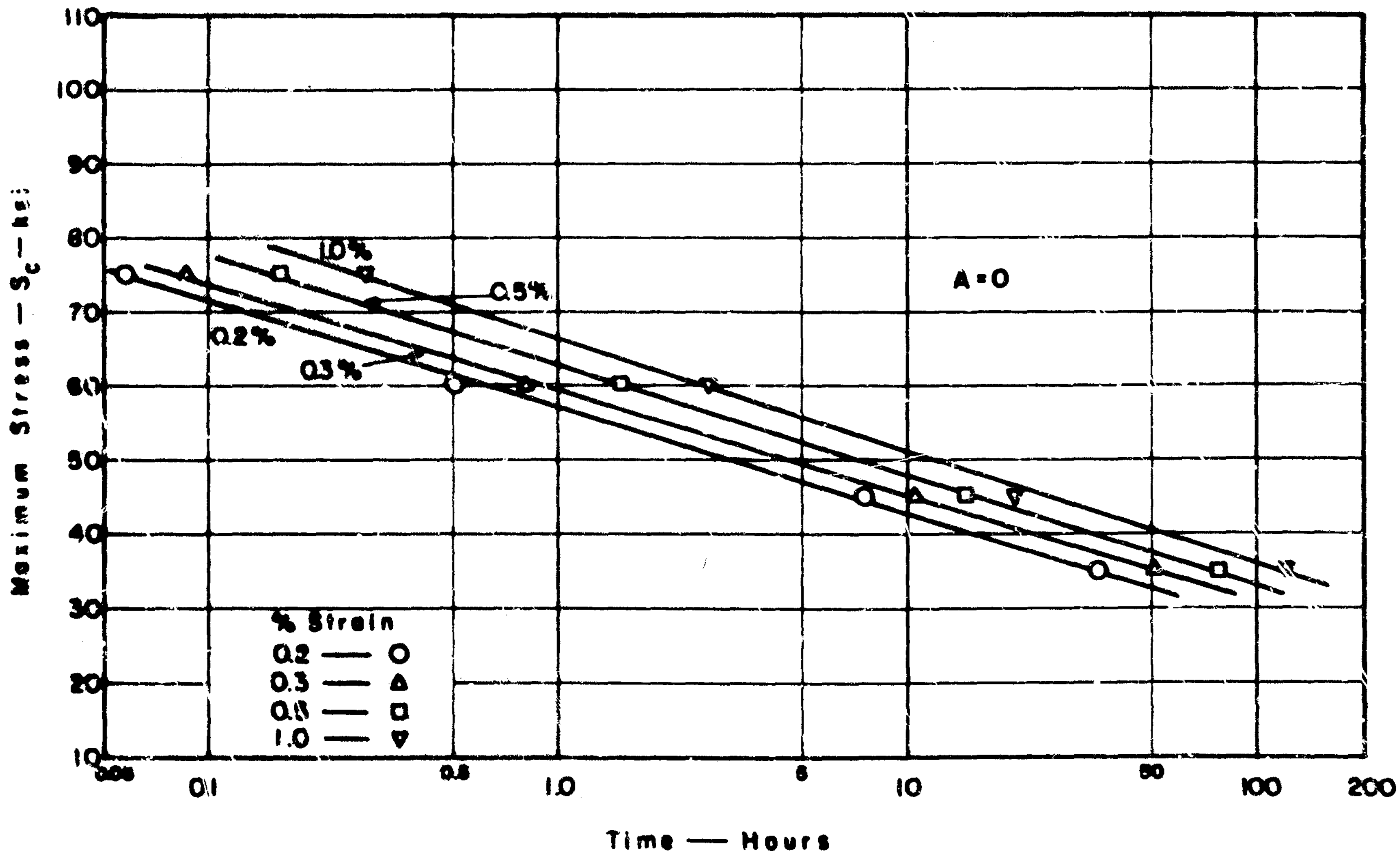


Figure 96 Maximum Stress Versus Time for Various Amounts of Creep for Longitudinal Inconel 718 Sheet Under Static Load (A = 0) at 1400°F.

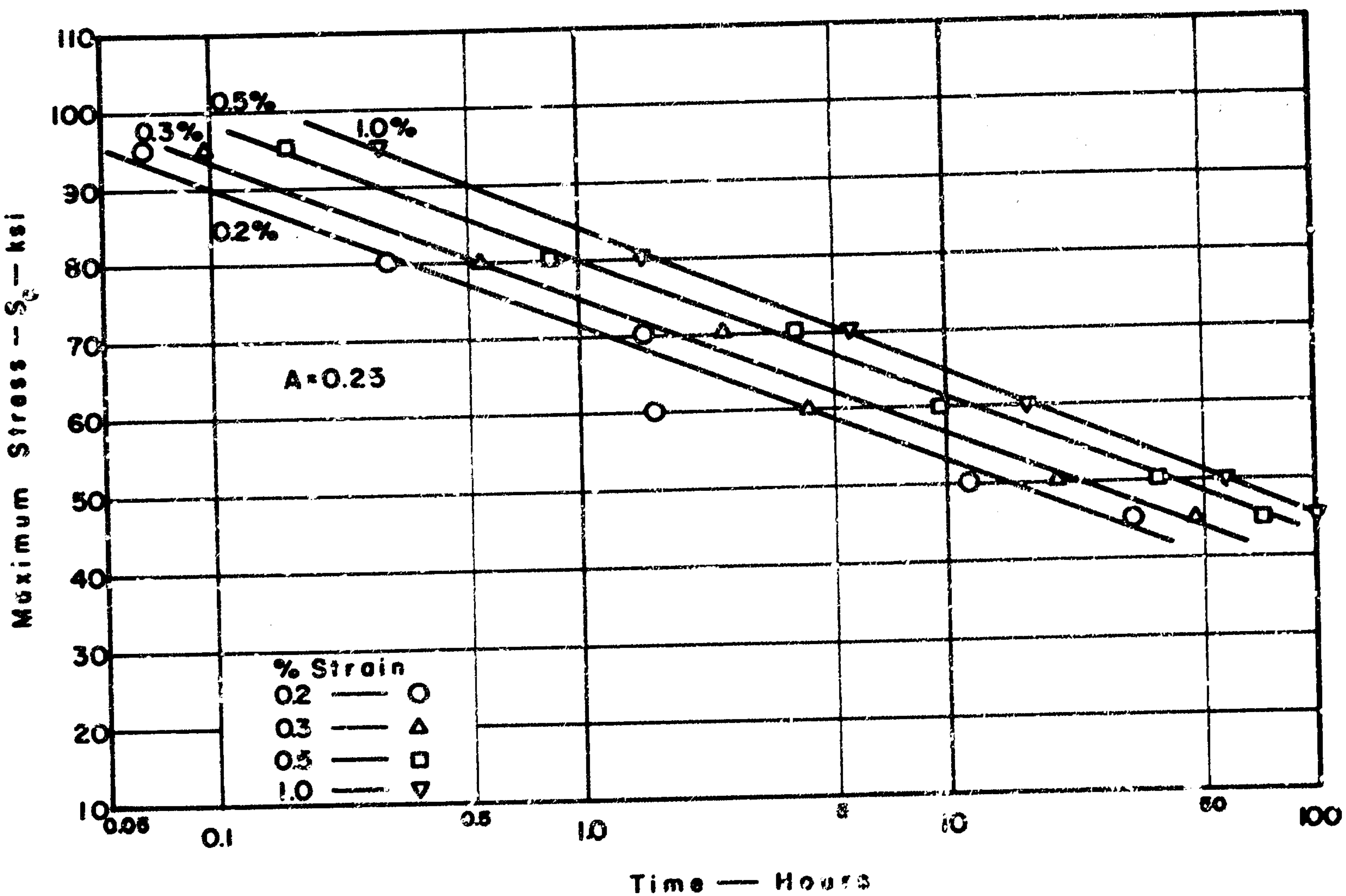


Figure 97 Maximum Stress Versus Time for Various Amounts of Creep for Transverse Inconel 718 Sheet at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1400°F.

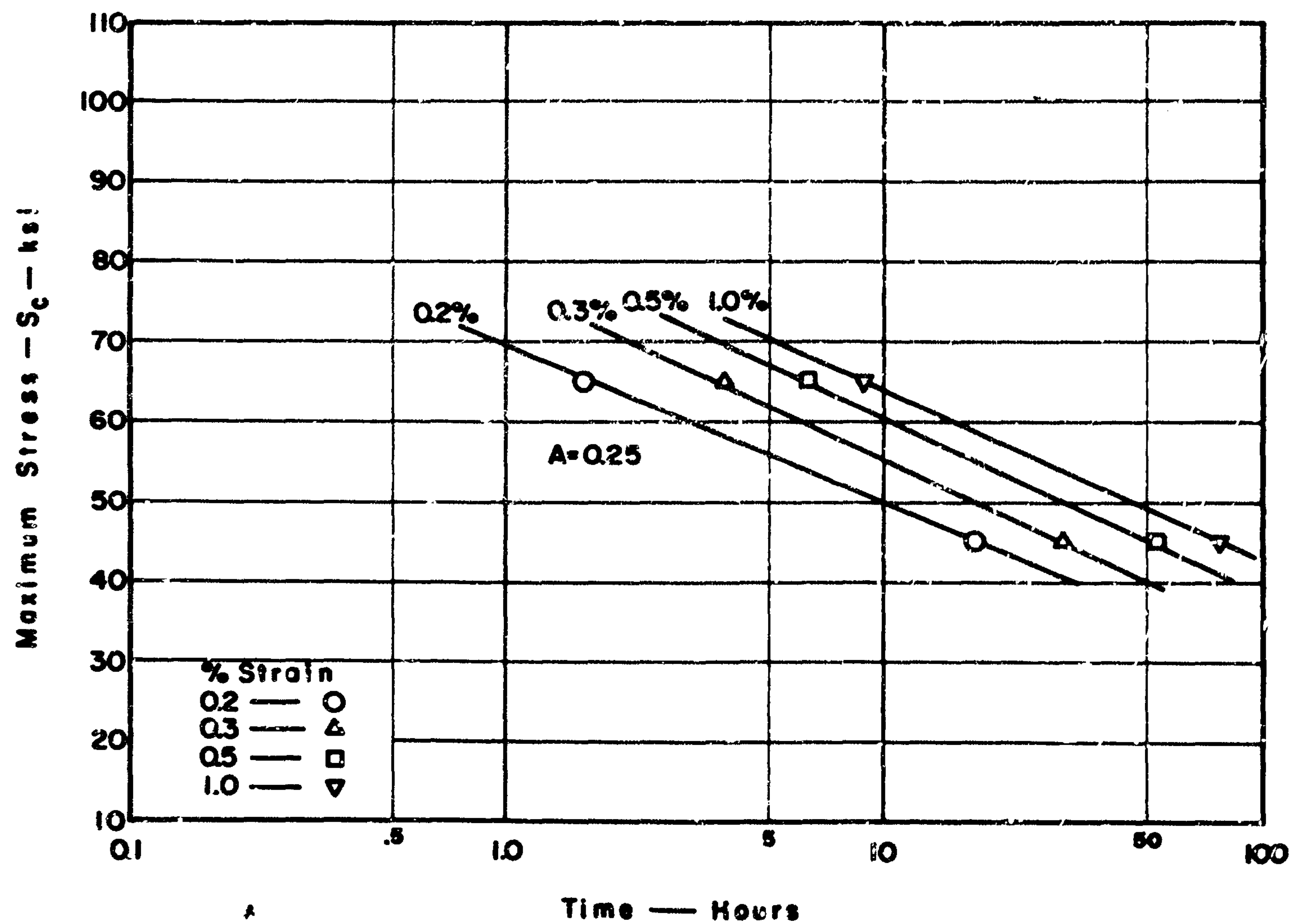


Figure 98 Maximum Stress Versus Time for Various Amounts of Creep for Longitudinal Inconel 718 Sheet at an Alternating-to-Mean Stress Ratio of A = 0.25 and at 1400°F.

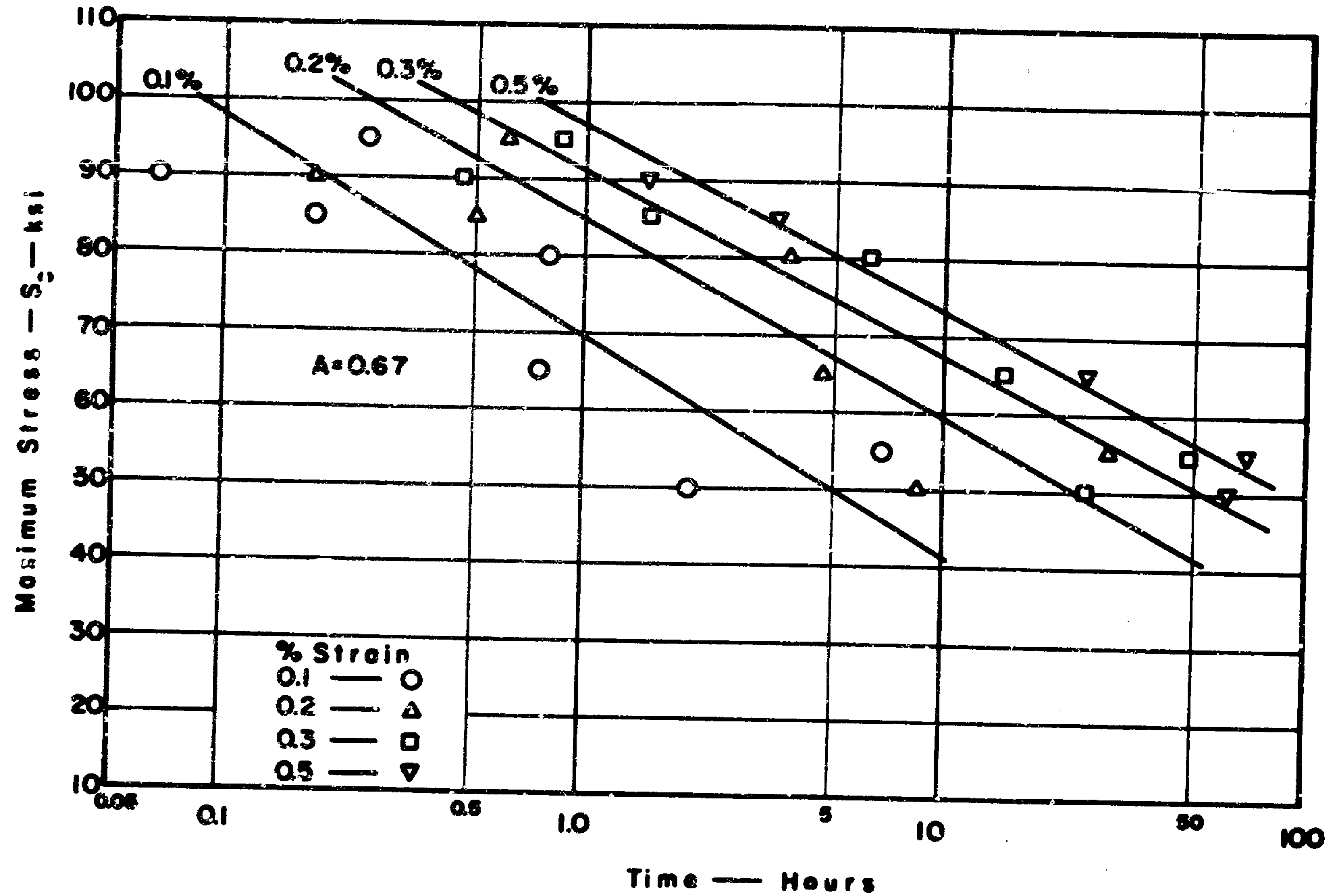


Figure 99 Maximum Stress Versus Time for Various Amounts of Creep for for Transverse Inconel 718 Sheet at an Alternating-to-Mean Stress Ratio of A = 0.67 and at 1400°F.

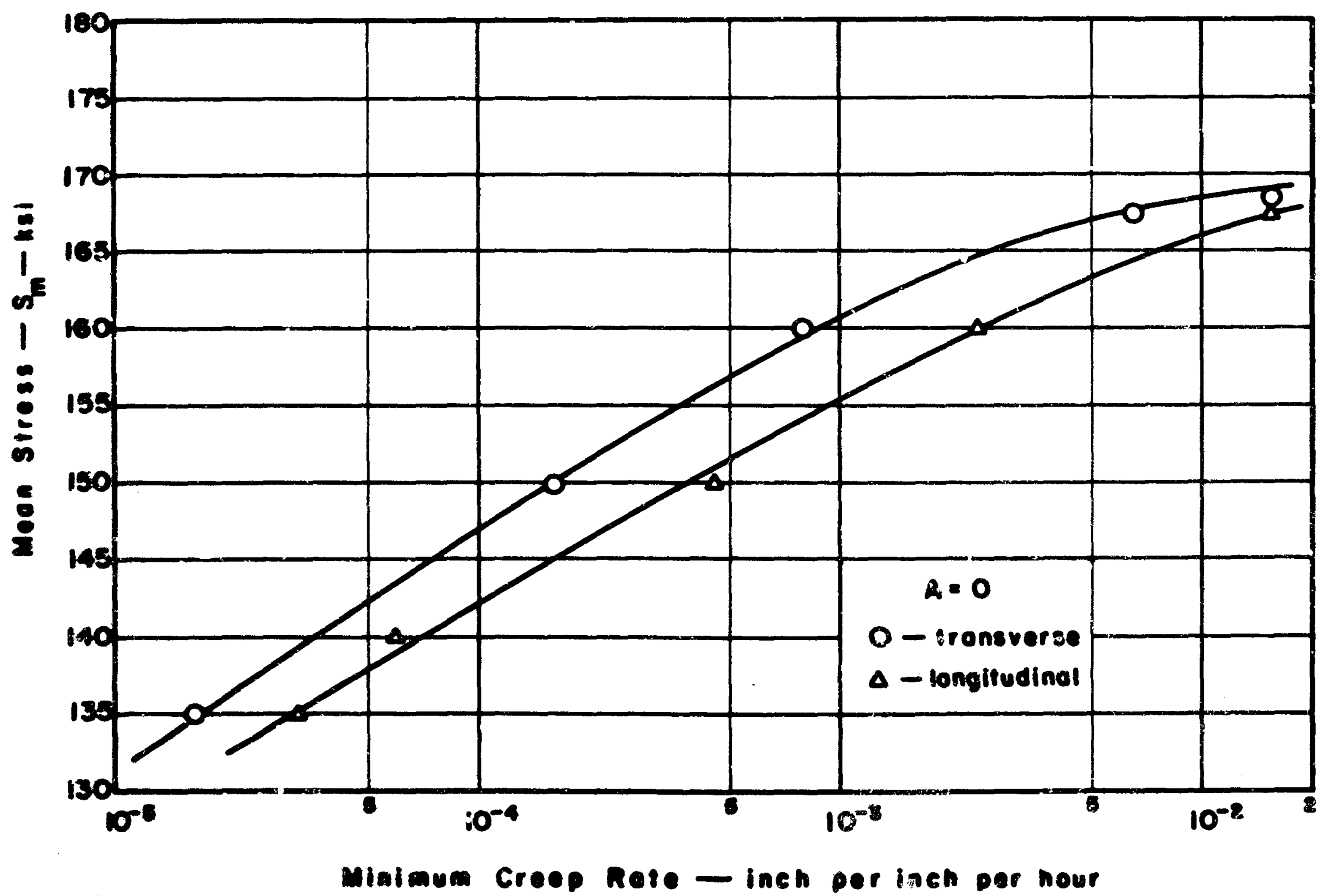


Figure 100 Minimum Creep Rate Versus Mean Stress for Transverse and Longitudinal Inconel 718 Sheet Under Static Load (A = 0) at 1000°F.

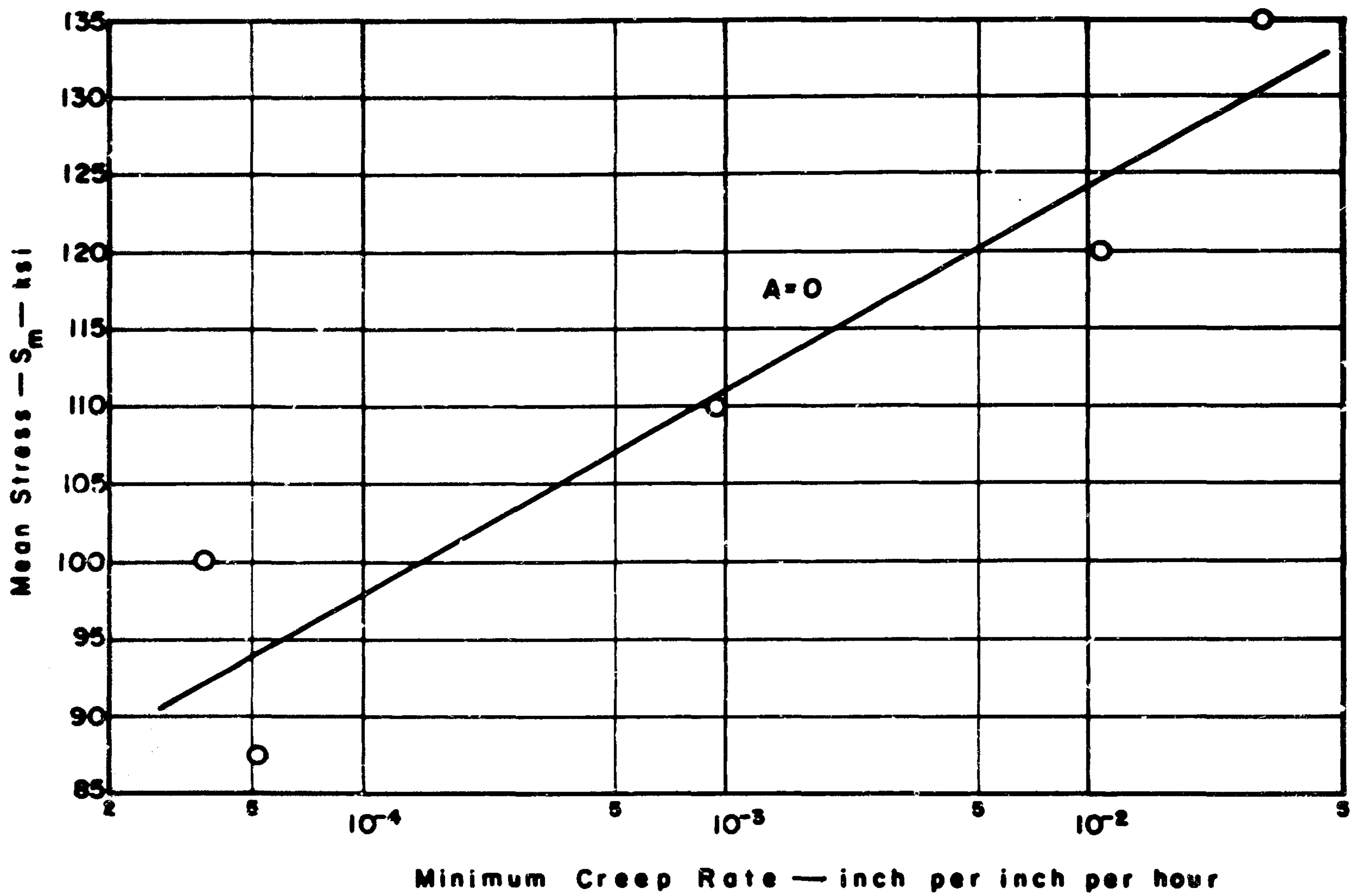


Figure 101 Minimum Creep Rate Versus Mean Stress for Transverse Inconel 718 Sheet Under Static Load (A = 0) at 1200°F.

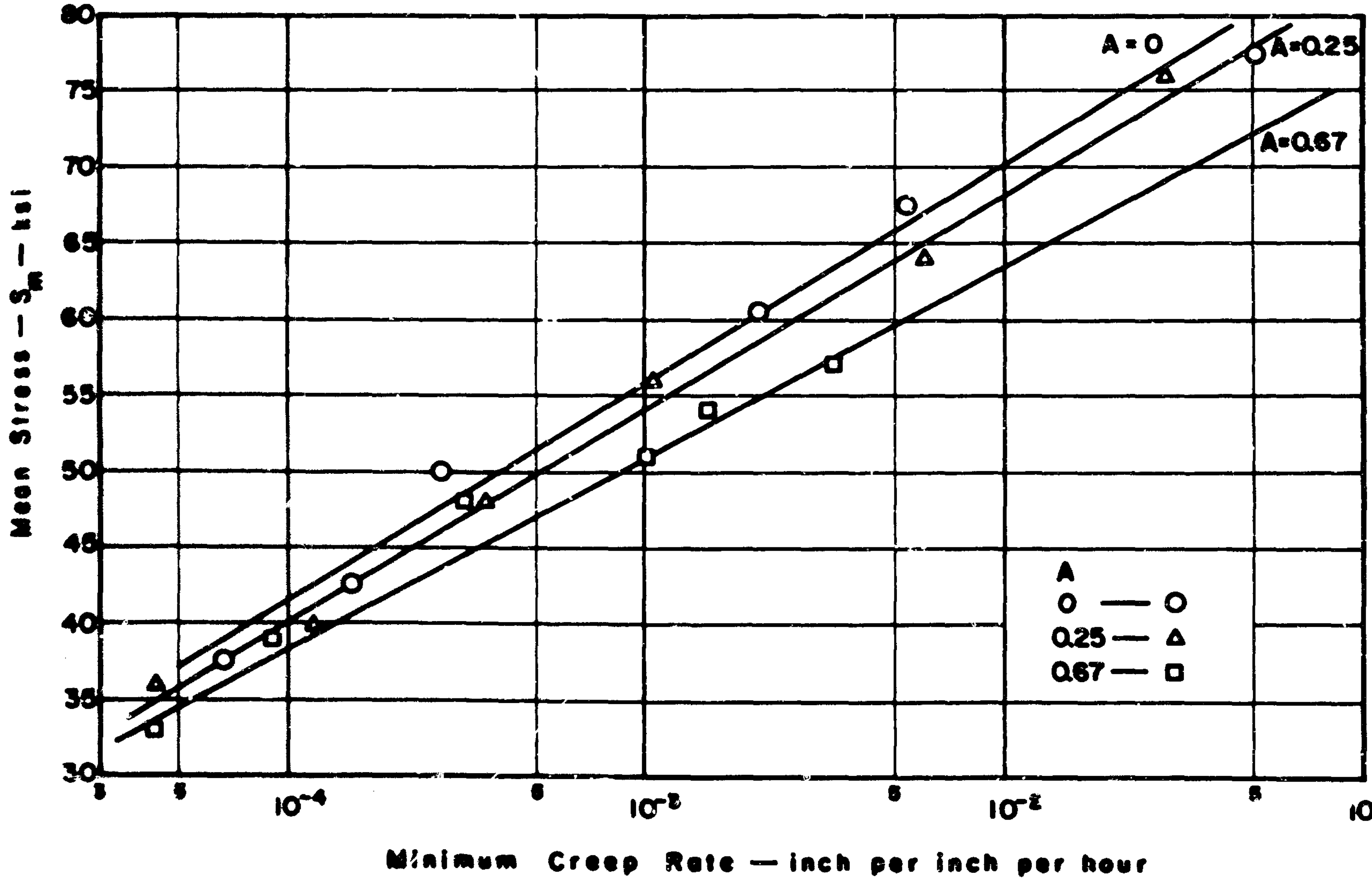


Figure 102 Minimum Creep Rate Versus Mean Stress for Transverse Inconel 718 Sheet at Various Alternating-to-Mean Stress Ratios and at 1400°F.

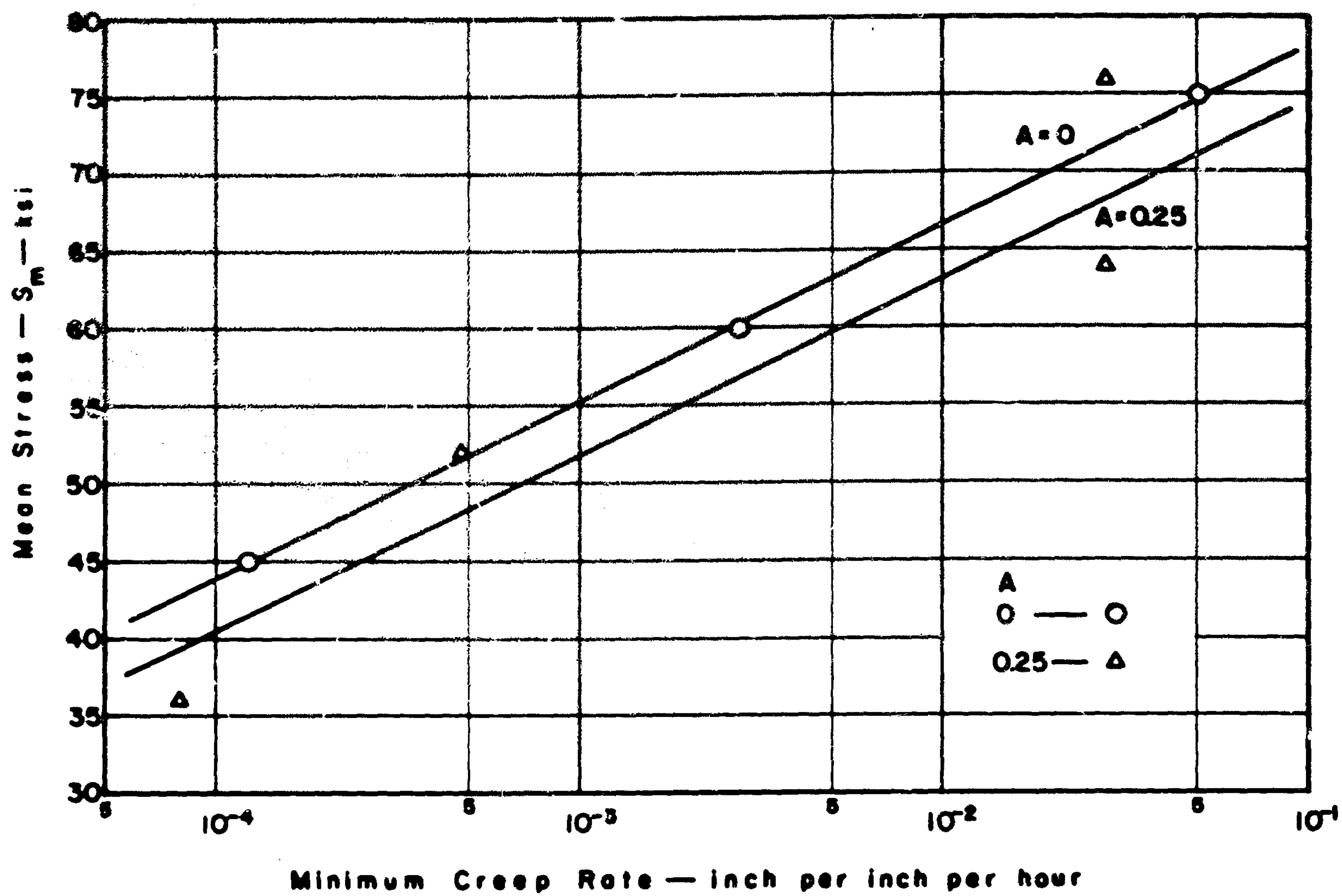


Figure 103 Minimum Creep Rate Versus Mean Stress for Longitudinal Inconel 718 Sheet at Alternating-to-Mean Stress Ratios A = 0 and 0.25 and at 1400°F.

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13. ABSTRACT

The fatigue, creep, and stress rupture properties of three super alloys: Nicrotung, Super A-286, and Inconel 718 were determined at elevated temperatures. The specimens of Nicrotung were investment cast, Super A-286 were machined from bar stock, while the Inconel 718 was tested in sheet form. The specimens were tested in axial-stress machines.

Fatigue and stress-rupture data are presented in the form of S-N diagrams, and the effect of combinations of alternating and mean stresses is shown by means of stress range diagrams. Creep data are given in the form of creep-time curves, and for design purposes creep strength curves are presented.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fatigue						
Creep						
Nicrotung						
Super A-286						
Inconel 718						
Elevated Temperature						
Strength						

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